
# NUCLEAR CRITICALITY SAFTEY PROGRAM (NCSP)

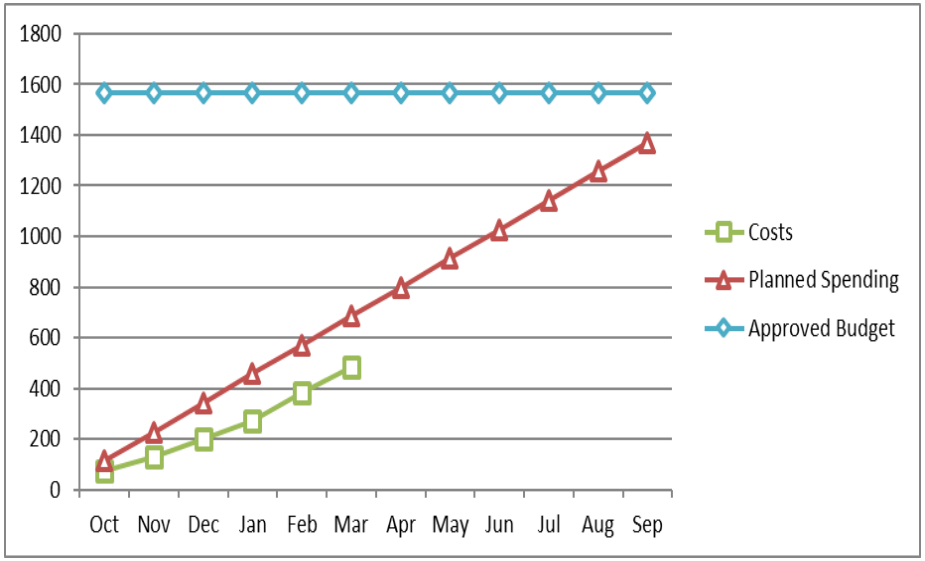
## FY2018 Q2 QUARTERLY REPORTS

# NCSP Quarterly Progress Report (FY-2018 Q2)

NCSP Element and Subtask: AM1/AM2/AM4 (MCNP/NJOY/USL Comparison Study)
M&O Contractor Name: LANL
Point of Contact Name: Bob Margevicius / Bob Little
Point of Contact Phone: 505-665-8965 / 505-665-3487

Reference: B&R DP0902090
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $0.
2. Approved FY-2018 Budget = $1,567,000 (Includes carryover from FY-2017).
3. Actual Spending through the end of this quarter in FY-2018 = $486,599.
4. Projected carryover into FY 2019 = $200,000.

## ACCOMPLISHMENTS

**MCNP**

- **Education**
  - **Completed Q3 Milestone:** MCNP Criticality class, LANL, 4 students. Y12 class scheduled for June 2018.
  - Taught classes at UNM & LANL, "Advanced Computational Methods for Monte Carlo Calculations", LA-UR-18-20247. 8 students at UNM & about 12 at LANL.
  - Thesis advisor for 2 UNM graduate students working in area of criticality calculations.

- **R&D Work**
  - Continued effort to apply region-dependent sensitivity-uncertainty data to NCS validation.
  - Continued to develop fission matrix methods to diagnose & accelerate MC source convergence.
  - Continued to investigate the impact of correlated fission multiplicity models in criticality calculations.
  - Collaborations with LANL groups NCS, C-AAC and NEN-2 on further studies into the validation for chlorine.
  - Investigated the impact of excluding benchmark outliers on the Whisper selection of similar benchmarks & on the Whisper baseline-USLs.

- **Support & Maintenance**
  - **Completed Milestone:** MCNP6.2 & Whisper released through RSICC.
  - **Completed Q2 Milestone:** Performed MCNP6.2 verification-validation study for NCS applications (report is in progress).
  - Developed a cross-walk between recently revised standards: ANS-8.24-2017 & ANS-8.24-2007, and DOE-STD-3007-2007 & DOE-STD-3007-2017. Reviewed how the standards are supported by MCNP6-Whisper sensitivity-uncertainty methods.

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

| | |
|---|---|
| | ○ Code modernization effort - Efforts are in progress to improve SQA, implement some MCNP-2020 features, & upgrade portions of MCNP6. Includes more formal planning, design proposals, improved code review, SQA tools, and more. (Most of funding is non-NCSP.)<br><br>• **Professional society meetings**<br>○ Participated in the NCSP Technical Program Review meeting, and presented a talk on "MCNP Progress for NCSP."<br>○ Organized & participated in the NCSP Analytical Methods Working Group meeting held during the TPR week.<br>○ Helped to organize 3 MCNP-related workshops for the August 2018 ANS RPSD Topical meeting.<br><br>• **Reports & Publications (available in MCNP Reference Collection on web)**<br>○ C.J. Werner, et al., "MCNP Version 6.2 Release Notes", LA-UR-18-20808 (2018)<br>○ F.B. Brown, "Advanced Computational Methods for Monte Carlo Calculations", LA-UR-18-20247 (2018)<br>○ C.J. Josey, F.B. Brown, "A New Monte Carlo Alpha-Eigenvalue Estimator with Delayed Neutrons", Trans. ANS 118, June 2018, LA-UR-18-20541 (2018)<br>○ J.L. Alwin, "MCNP6 Unstructured Mesh (UM) for Criticality Accident Alarm System (CAAS) Analysis", ANS-RPSD 2018, Santa Fe NM, LA-UR-18-21577 (2018)<br>○ M.E. Rising, F.B. Brown, J.L. Alwin, "MCNP Progress for NCSP", NCSP Technical Program Review, March 2018, LA-UR-18-22379 (2018)<br>○ M.E. Rising, et al., "MCNP Version 6.2: New Features and Tools for RPSD Applications", ANS-RPSD Topical Meeting, August, 2018, LA-UR-18-22358, (2018)<br>○ K.L. Currie, M.E. Rising, "MCNP6 Source Primer: Release 1.0", LA-UR-18-21377 (2018)<br>○ J.A. Arthur, et al., "Validating the performance of correlated fission multiplicity implementation in radiation transport codes with subcritical neutron multiplication benchmark experiments", submitted to Physical Review C, LA-UR-17-31332 (2018) |

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

| | |
|---|---|
| | ○ M.T. Andrews, et al., "Fission Neutron Angular Correlation Measurements and MCNP6.2 Simulations", SORMA 2018, Ann Arbor MI, LA-UR-18-21255 (2018)<br>○ P. Talou, et al., "Correlated Prompt Fission Data in Transport Simulations", European Journal of Physics A: Hadrons and Nuclei, Vol 54, issue 1, LA-UR-17-28181 (2018)<br>○ Los Alamos NCSP / AM staff co-authored four of the articles in the Nuclear Data Sheets special issue on Nuclear Reaction Data focused on the release of ENDF/B-VIII.0, which appeared in February 2018 (https://www.sciencedirect.com/journal/nuclear-data-sheets/vol/148/suppl/C)<br><br>**NJOY**<br>• We continue to respond to user questions and requests for NJOY, providing updates as required.<br>• In April we held a successful 3-day NJOY class at LANL (seven students). We also held a 4-hour workshop at the PHYSOR2018 conference that was attended by 20 people.<br>• We have processed ENDF/B-VIII.0 and are preparing it for worldwide release. We have discovered an issue with PURR that has delayed the release of the data a bit, but shouldn't cause us to miss out Q3 milestone.<br>• We presented a paper at the PHYSOR2018 conference, "Resonance Reconstruction Capabilities in NJOY21" by Jeremy Lloyd Conlin, Austin P. McCartney, Wim Haeck, and Amelia Jo Trainer. A talk with the same title was presented at the TPR in March. |

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

| MILESTONES | | ISSUES/PATH FORWARD |
|---|---|---|
| Provide status reports on LANL participation in US and International Analytical Methods collaborations (AM1, AM2: All Qtrs) | | |
| Support MCNP6 users (AM1: All Qtrs) | | |
| Support NJOY Users (AM2: All Qtrs) | | |
| Provide reports on summer intern work accomplished (AM1: Q1) | | |
| Develop a plan to distribute ACE files independent of MCNP releases (AM1: Q1) | | |
| Issue an MCNP V&V report (AM1: Q2) | | |
| Provide training course on theory and practice of Monte Carlo criticality calculations with MCNP6 (AM1: Q3) | | |
| Release MCNP ACE data libraries corresponding to ENDF/B-VIII.0 (AM1: Q3) | | |
| Develop Doppler broadening capabilities in NJOY21 (AM2:Q4) | | |
| Issue report on the Sensitivity-Uncertainty Comparison Study (AM4: Q4) | | |
| Develop a report for the NCSP manager on MCNP maintenance and modernization progress, the implementation of a parallel PTRAC capability, and the implementation of a Fission Matrix automated convergence checking capability (AM1: Q4) | | |
| Issue a report on development and maintenance of the NJOY nuclear data processing code system (AM2:Q4) | | |

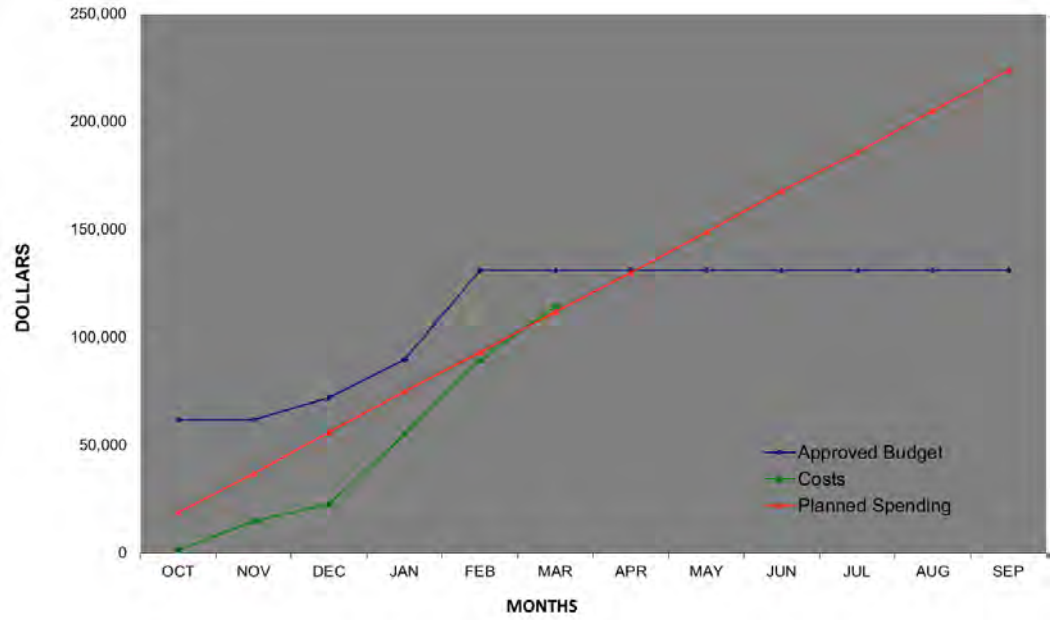
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtasks: Analytical Methods,
LLNL Analytical Methods (AM1), Sliderule (AM3), Analytic Benchmarks (AM6)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $17,016
2. Approved FY-2018 Budget = $260,016 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter (in FY-2018) = $114,547
4. Projected carryover into FY-2019 = $21,000 (8%)

## ACCOMPLISHMENTS

LLNL Analytical Methods (AM1)

- Successfully processed the ADVANCE project ENDF/B-VIII.0 library in ACE format using ACEtoCOG. Identified 50 isotopes with 'bad' data occurring in LAW=61 for the (n,Xg) reaction (MT=5). 53 other isotopes with this reaction are OK. Detailed results were reported to Dave Brown. This problem was found to also exist in JEFF3.2 ACE-formatted data.
- Commenced processing JEFF3.3 data in ACE format.
- Provided high-precision COG benchmark results for 356 HEU and 143 PU ICSBEP benchmark cases for inclusion in the *Benchmark Inter-comparison Study* presented by Isabelle Duhamel (IRSN) at the NCSP Analytical Methods Working Group Meeting on March 26, 2018.

Criticality Sliderule (AM3)

- Completed all calculations of the specification for phase 3 of the Criticality Sliderule project using COG; namely:
  - Air moisture (Q2)
  - Ground effects (i.e., soil, concrete) (Q1)
  - Skyshine (Q2)
  - Shielding (i.e., steel, lead, water, concrete) (Q2)
- A subset of these COG results are included in the *Update of the Nuclear Criticality Slide Rule Calculations - Studies with Common Shielding Materials* for presentation at the American Nuclear Society 20th Topical Meeting of the Radiation Protection & Shielding Division in Santa Fe, NM, August 26-31, 2018.
- Participated in the Sliderule VTC on February 21, 2018.

Analytic Benchmarks (AM6)

- LLNL commenced work on establishing a contract or consultant agreement with Dr. Barry Ganapol (University of Arizona).

## MILESTONES FY2018

| | |
|---|---|
| Provide status on LLNL AM activities in NCSP Quarterly Progress Reports (AM2, AM3 and AM6: All Qtrs). | |
| Provide an annual report on the LLNL multiphysics capability development (AM2). | |

## ISSUES/PATH FORWARD

- Approved budget reflects the actual funds received on October 13, 2017; December 22, 2017; January 12, 2018; February 8, 2018; and February 27, 2018.

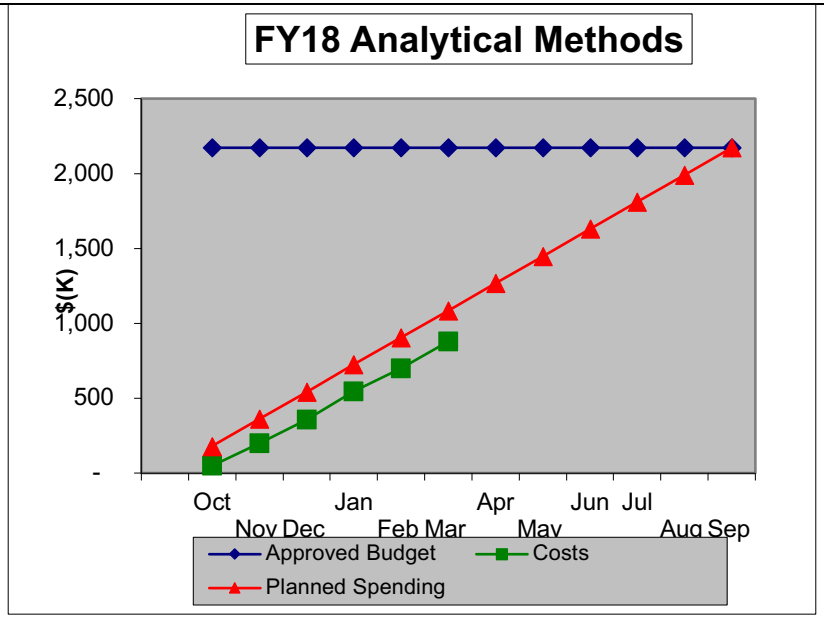
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

**NCSP Element and Subtask:** ORNL – AM1, 2, 3, 6, 9, 11, 13, 14
M&O Contractor Name: ORNL
**Point of Contact Name:** Doug Bowen
**Point of Contact Phone:** (865) 576-0315

**Reference: DP0902000/ORNL**
**Date of Report: May 04, 2018**

## BUDGET




1. **Carryover into FY 2018** = $50K
2. **Approved FY 2018 Budget** = $2172K (includes carryover
3. **Actual spending for 1st Quarter FY 2018** = $357K
4. **Actual spending for 2nd Quarter FY 2018** = $523K
5. **Actual spending for 3rd Quarter FY 2018** = $
6. **Actual spending for 4rd Quarter FY 2018** = $

## ACCOMPLISHMENTS

**AM1 – Distribution of available and newly packaged software**

- Distributed 817 software packages and updated 1 software package.
- 222 SCALE, 385 MCNP®, and 0 COG packages distributed.
- RSICC quarterly report issued.

**AM2 - IRSN Area of Collaboration – SCALE/KENO/TSUNAMI**

- **Status report on all ORNL participation in US and International analytical methods collaborations and travel.**
  - SCALE Stats:
    - Answered 195 requests for user assistance through scalehelp@ornl.gov.
    - Since 2004, there have been over 13,650 distributions of SCALE to 8630 unique users in 58 nations.
    - Since April 2016, the distribution centers have issued licenses for 3,849 copies of the latest SCALE version.
    - Held 2 weeks of SCALE training courses at ORNL in February. Total attendance - 22 people. See attached document for more info and photos.
    - Held 2 weeks of SCALE training courses at the NEA Databank in Paris in March. Total attendance - 26. See attached document for more info.
    - Held a week of SCALE training at North Carolina State University in March. Total attendance - 12. See attached document for more info.
  - Distributed 36-page Fiscal Year 2017 Report on SCALE Maintenance and Development that includes the following sections:
    - Manager's Statement
    - Sponsor Acknowledgements
    - SCALE Releases
    - Capabilities of SCALE
    - SCALE Distribution
    - Training Courses and Workshops
    - SCALE Users' Group Workshop
    - SCALE Maintenance and Development Activities

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

| **NCSP Element and Subtask:** ORNL – AM1, 2, 3, 6, 9, 11, 13, 14<br>M&O Contractor Name: ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference: DP0902000/ORNL**<br>**Date of Report: May 04, 2018** |
|---|---|
| **BUDGET** | **ACCOMPLISHMENTS** |
| | **AM2 - IRSN Area of Collaboration – SCALE/KENO/TSUNAMI (Continued)**<br>▪ Quality Assurance<br>▪ Development Coordination<br>▪ Sponsored Activities<br>▪ ** Please see attached cover image<br><br>• Responded to user community with a SCALE User Notice issued on March 8, 2018 according to the SCALE Quality Assurance plan after an issue was identified in SCALE 6.1-6.2.2 with KENO-V.a in which unexpected behavior occurs if the input assigns albedo boundary conditions to a non-cuboid region, contrary to the documentation, which states "Albedo boundary conditions are applied only to the outermost region of a problem. In KENO V.a this geometry region must be a rectangular parallelepiped." This error is now properly caught by input checking in SCALE 6.2.3.<br><br>o Prepared numerous enhancements for the release of SCALE 6.2.3 including the following criticality safety features:<br>▪ An issue was identified in SCALE 6.1-6.2.2 with KENO-V.a in which unexpected behavior occurs if the input assigns albedo boundary conditions to a non-cuboid region, contrary to the documentation, which states "Albedo boundary conditions are applied only to the outermost region of a problem. In KENO V.a this geometry region must be a rectangular parallelepiped." This error is now properly caught by input checking in SCALE 6.2.3.<br>▪ The multigroup cross section self-shielding method selection logic (BONAMI or CENTRM) includes improved consistency across all sequences and now enables the use of BONAMI-only methodology for faster calculations or for cases in which the CENTRM methodology is not suitable.<br>▪ Numerous other stability, usability, and documentation enhancements are also included. |

| NCSP Element and Subtask: ORNL – AM1, 2, 3, 6, 9, 11, 13, 14<br>M&O Contractor Name: ORNL<br>Point of Contact Name: Doug Bowen<br>Point of Contact Phone: (865) 576-0315 | Reference: DP0902000/ORNL<br>Date of Report: May 04, 2018 |
|---|---|
| | **AM2 - IRSN Area of Collaboration – SCALE/KENO/TSUNAMI (Continued)**<br>o Continued modernization initiatives for SCALE 6.3 including:<br>▪ Testing ENDF/B-VIII.0 nuclear data<br>▪ Investigating methods for improved used of covariance data, especially in light of the new ENDF/B-VIII.0 disclaimer regarding the suitability of covariance data for use in applications<br>▪ Integration of Shift Monte Carlo code modernized alternative to KENO V.a, KENO-VI, and Monaco for all SCALE sequences<br>▪ Updating USLSTATS package to modern software standards and integration with the Fulcrum user interface<br>▪ Addition of 3D geometry visualization capabilities in Fulcrum<br><br>**AM3 - IRSN Area of Collaboration – AMPX**<br>• **Status report on all ORNL participation in US and International analytical methods collaborations and travel.**<br>o Since ENDF/VIII.0 was released, we processed CE and MG libraries for ENDF/VIII.0.<br>▪ The libraries contain data for many new moderators, like graphite with different porosity and ice. This makes an update in the Standard Composition library necessary that is used by SCALE, so that the new moderator can be used in a transport calculation.<br>▪ The new libraries along with the updated Standard Composition library are available in a repository for general testing in ORNL.<br>▪ The VALID suite has been run and preliminary results were presented at the TPR meeting. |

| NCSP Element and Subtask: AM1, 2, 3, 6, 9, 11, 13, 14<br>M&O Contractor Name: ORNL<br>Point of Contact Name: Doug Bowen<br>Point of Contact Phone: (865) 576-0315 | Reference: DP0902000/ORNL<br>Date of Report: May 04, 2018 |
|---|---|

**AM3 - IRSN Area of Collaboration – AMPX (continued)**

- Since the ENDF/VIII.0 library is to be released in GNDS format, we also continued to work on supporting GNDS formatted data in AMPX.
  - Polident, our code that processes 1-D data, can now read 1-D data (excepting nubar) from a GNDS file.
  - Data processed from ENDF formatted and GNDS formatted files were processed for all incident neutron files in ENDF/VIII.0 and compared to ensure correct processing. Minor inconsistencies in the resolved resonance formatting were reported back to the FUDGE team in LLNL, which addressed the issues.

**AM6 – AWE and IRSN Area of Collaboration – SlideRule (Thomas Miller, Lead)**

- **Status report on ORNL support**
  - All KENO simulations to generate prompt neutron sources for the FY18 work are complete.
  - Presented a summary of FY17 activities and plans for FY18 activities at the NCSP TPR.
  - Investigated differences between simulations using delayed gamma sources generated by ORIGEN and COG. Differences do exist, but they are not significant in terms of a shielding calculation. Further investigation to pinpoint the exact cause of the differences is beyond the scope of this project.

**AM9 – IRSN Area of Collaboration – TSUNAMI**

- **Status report on ORNL support (Thomas Miller, Lead)**
  - Discussions with LANL and IRSN to get this work started were held at the analytical methods meeting during the NCSP TPR.
  - ORNL provided IRSN results of ICSBEP benchmark simulations used to validate SCALE/KENO. ORNL, LANL, and IRSN will calculate a baseline USL for an agreed upon application(s) using their own methods. The application(s) will be selected from the common ICSBEP benchmark models already available at each lab.

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

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|---|---|
| **NCSP Element and Subtask:** AM1, 2, 3, 6, 9, 11, 13, 14<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference: DP0902000/ORNL**<br>**Date of Report: May 04, 2018** |
| | **AM11 – U. of Arizona and LLNL Area of Collaboration**<br>• We have not yet heard from LLNL/U. of Arizona to initiate this task. This task has been assigned and contact with LLNL will be made in the near future.<br><br>**AM13 – U of Florida Area of Collaboration**<br>• Contract has been set up with U. of Florida. This university task will fund an MS student over the next two years.<br><br>**AM14 - U. of Tennessee Area of Collaboration**<br>• Contract has been set up with U. of Florida. This university task will fund an MS student over the next two years. |

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

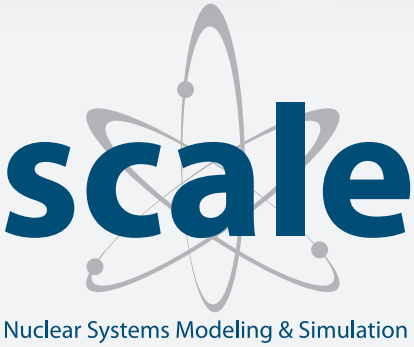
| **NCSP Element and Subtask:** AM1, 2, 3, 6, 9, 11, 13, 14<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | | **Reference: DP0902000/ORNL**<br>**Date of Report: May 04, 2018** |
|---|---|---|
| **MILESTONES** | **Status** | **ISSUES/PATH FORWARD** |
| 1. Provide status reports on all analytical method support activities in NCSP Quarterly Progress Reports (AM1, AM2, AM3, AM6, AM9, AM11: All Qtrs). | | |
| 2. Provide annual SCALE maintenance report (AM2: Q2). | | |
| 3. Publish annual newsletter (AM2: Q4) | | |
| 4. Document AMPX modernization and technical support (AM3: Q4) | | |
| 5. Complete annual IRSN-LLNL-ORNL status report (AM6: Q4) | | |
| 6. Complete summary report on TSUNAMI results (AM9: Q4) | | |
| 7. Status report of progress on acquiring and processing the latest beta and official releases of ENDF/B-VIII.0 with AMPX (AM13: Q1) | | **Task delayed due to CR issues. Recovery in progress.** |
| 8. Status report for running verification test cases and comparing results (AM13: Q3) | | |
| 9. Summary report for nuclear data and cross section testing using ENDF/B-VIII.0 (AM13: Q4) | | |
| 10. Status report on VALID progress (AM14: Q1) | | **Task delayed due to the CR issues. Recovery in progress.** |
| 11. Status report running CE TSUNAMI-3D models (AM14: Q2) | | |
| 12. Status report for VALID and submit paper to winter ANS or NCSP professional conference (AM14: Q3) | | |
| 13. Status report on lessons learned, results and feedback for ORNL and final report for NCSP and ORNL (AM14: Q4) | | |



Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

OAK RIDGE National Laboratory

ORNL/SPR-2018/20




# Fiscal Year 2017 Report on SCALE Maintenance and Development

## DOCUMENT AVAILABILITY

Reports produced after January 1, 1996, are generally available free via US Department of Energy (DOE) SciTech Connect.

***Website:*** http://www.osti.gov

Reports produced before January 1, 1996, may be purchased by members of the public from the following source:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
***Telephone:*** 703-605-6000 (1-800-553-6847)
***TDD:*** 703-487-4639
***Fax:*** 703-605-6900
***E-mail:*** info@ntis.gov
***Website:*** http://classic.ntis.gov

Reports are available to DOE employees, DOE contractors, Energy Technology Data Exchange representatives, and International Nuclear Information System representatives from the following source:

Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831
***Telephone:*** 865-576-8401
***Fax:*** 865-576-5728
***E-mail:*** reports@osti.gov
***Website:*** http://www.osti.gov/contact.html



18-G00084/cae


## MISSION STATEMENT

Develop, deploy, and support a quality-assured computational toolkit that advances the state of the art and exemplifies ease of use in a scalable architecture beginning with fundamental physical data and providing research, production, and licensing calculations for current and emerging nuclear modeling and simulation needs.

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# MANAGER'S STATEMENT


## Bradley Rearden

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## William Wieselquist

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The SCALE team is pleased to present this annual report documenting the development, maintenance, distribution, and training accomplishments from fiscal year 2017 (FY17). The SCALE 6.2 release has been very well received. We have distributed over 3,000 licenses as of September 2017 and have added over 900 new users. Our total user base now exceeds 8,000 individuals. The SCALE User Interaction and Training Team has updated the training course material to emphasize the new capabilities of SCALE 6.2, focusing on Polaris, Sampler, and the Fulcrum user interface. These courses continue to be in high demand through public offerings and through several onsite courses focused on the needs of individual teams.

We held the first-ever SCALE Users' Group Workshop in September 2017, attracting 130 attendees, including users from the US Nuclear Regulatory Commission (NRC), the US Department of Energy (DOE), several national laboratories, industry, and academia, as well as international participants. After receiving positive feedback from the attendees, we plan to make the Users' Group Workshop an annual event.

Based on the growing interest in advanced reactors and advanced technology fuels, several NRC-sponsored initiatives are under way to provide resources for the design and licensing of these new systems. More information on these activities can be found in Section 6.5, "Ongoing Development."

SCALE leadership personnel were honored to receive a Technical Excellence Award from the American Nuclear Society (ANS) Nuclear Criticality Safety Division at the ANS Winter Meeting (Figure 1).


**Figure 1. 2017 ANS Nuclear Criticality Safety Division Technical Excellence Award**
*"For Technical Excellence in the Program Management of the SCALE System of Nuclear Safety Software Spanning Four Decades."* ***(Left to right)*** Cecil V. Parks (1980–1995), Stephen M. Bowman (1995–2009), and Bradley T. Rearden (2009–present)

Organizationally, we are pleased that Dr. William (Will) Wieselquist has joined our Leadership Team as Deputy Manager of the SCALE Code System. Will earned a PhD in Nuclear Engineering from North Carolina State University in 2009. From 2009 to 2012, he was a staff member at the Paul Scherrer Institute, where he established an uncertainty quantification platform for reactor core analysis. Will joined Oak Ridge National Laboratory (ORNL) in 2012 and quickly became the lead developer for the ORIGEN depletion/decay tools and the Sampler uncertainty quantification capabilities. Will is also a key developer of the Polaris lattice physics code. I am grateful to Dr. Matthew (Matt) A. Jessee for his commitment to excellence and tireless service over the past two years as Deputy Manager. Matt will continue to serve as a member of the SCALE Leadership Team while leading the development of Polaris, which has quickly gained the attention of the community and continues to expand with numerous new features.

We take great pride in the many capabilities provided by SCALE, and I hope you enjoy the contents of this annual report.

Sincerely,

Bradley T. Rearden, Ph.D.
Leader, Modeling and Simulation Integration
Reactor and Nuclear Systems Division

William A. Wieselquist, PhD
Deputy Manager, SCALE Code System
Reactor Physics Group

## Sustaining Sponsor Acknowledgments

**US Nuclear Regulatory Commission**
Mr. Andrew B. Barto
Office of Nuclear Materials Safety and Safeguards
Division of Spent Fuel Management
Criticality, Shielding and Risk Assessment Branch

Dr. Mourad Aissa
Mr. Don Algama
Office of Nuclear Regulatory Research
Division of Systems Analysis
Fuel and Source Term Code Development Branch

**National Nuclear Security Administration**
Dr. Angela Chambers
Office of the Chief of Defense Nuclear Safety, NA-511
Manager, DOE Nuclear Criticality Safety Program

**US Department of Energy**
Dr. James M. Shuler
Office of Environmental Management, EM-33
Manager, DOE Packaging Certification Program

## Collaborating Sponsor Acknowledgments

**Consortium for the Advanced Simulation of LWRs**

**US Department of Energy**
Nuclear Energy Advanced Modeling and Simulation Program

## Acronyms

- 1D — one-dimensional
- 2D — two-dimensional
- 3D — three-dimensional
- AEC — US Atomic Energy Commission
- API — application programming interface
- ATF — advanced technology fuel
- CADIS — Consistent Adjoint Driven Importance Sampling
- CAS — Chinese Academy of Sciences
- CASL — Consortium for the Advanced Simulation of LWRs
- CE — continuous-energy
- CPU — central processing unit
- DOE — US Department of Energy
- DSFM — Division of Spent Fuel Management
- ENDF — evaluated nuclear data file
- ENSDF — evaluated nuclear structure data file
- ESSM — Embedded Self-Shielding Methodology
- ExSITE — Extensible SCALE Intelligent Text Editor
- FHR — Fluoride salt-cooled high-temperature reactor
- FW-CADIS — Forward-Weighted CADIS
- GLLS — generalized linear least squares
- GUI — graphical user interface
- HIVE — Hierarchical Input Validation Engine
- HTGR — high-temperature gas-cooled reactor
- I/O — input/output
- JEFF — joint evaluated fission and fusion file
- LWR — light water reactor
- MACCS — MELCOR Accident Consequence Code System
- MAVRIC — Monaco with Automated Variance Reduction using Importance Calculations
- MCDancoff — Monte Carlo Dancoff
- MCNP — Monte Carlo N-Particle
- MEPhI — Moscow Engineering Physics Institute
- MG — multigroup
- MOC — method of characteristics
- MSR — molten salt reactor
- NCSP — Nuclear Criticality Safety Program
- NE — DOE Office of Nuclear Energy
- NEA — Nuclear Energy Agency
- NEAMS — Nuclear Energy Advanced Modeling and Simulation
- NFST — Nuclear Fuels Storage and Transportation Planning Project
- NMSS — Office of Nuclear Material Safety and Safeguards
- NNSA — National Nuclear Safety Administration
- NRC — US Nuclear Regulatory Commission
- OECD — Organization for Economic Cooperation and Development
- ORIGAMI — ORIGEN Assembly Isotopics
- ORIGEN — Oak Ridge Isotope Generation
- ORNL — Oak Ridge National Laboratory
- PCP — packaging certification program
- QA — quality assurance
- RES — Office of Nuclear Regulatory Research
- RIST — Research Organization for Information Science and Technology
- RNSD — Reactor and Nuclear Systems Division
- SAMS — Sensitivity Analysis Module for SCALE
- SDF — sensitivity data file
- SFR — sodium-cooled fast reactor
- SKB — Svensk Kärnbränslehantering
- S/U — sensitivity/uncertainty
- SINAP — Shanghai Institute of Nuclear and Applied Physics
- TCF — Technology Commercialization Fund
- TRITON — Time-dependent Operation for Neutronic depletion
- TRISO — tristructural-isotropic
- TSAR — Tool for Sensitivity Analysis of Reactivity Responses
- TSUNAMI — Tools for Sensitivity and Uncertainty Analysis Methodology Implementation
- TSUNAMI-IP — TSUNAMI Indices and Parameters
- TSURFER — Tool for S/U Analysis of Response Functions Using Experimental Results
- USLSTATS — Upper Subcritical Limit Statistical Software
- VF — very fine
- VIBE — Validation, Interpretation and Bias Estimation
- WCS — Waste Control Specialists
- XSProc — Cross Section Processing

## Introduction

The SCALE code system is a widely used modeling and simulation suite for nuclear safety analysis and design that is developed, maintained, tested, and managed by the Reactor and Nuclear Systems Division (RNSD) of the Oak Ridge National Laboratory (ORNL). SCALE provides a comprehensive, verified and validated, user-friendly tool set for criticality safety, reactor physics, radiation shielding, radioactive source term characterization, and sensitivity and uncertainty analysis. Since 1980, regulators, licensees, and research institutions around the world have used SCALE for safety analysis and design. SCALE provides an integrated framework with dozens of computational modules that are selected based on the user's desired solution strategy. SCALE includes current nuclear data libraries and problem-dependent processing tools for continuous-energy (CE), multigroup (MG), and coupled neutron-gamma calculations, as well as activation, depletion, and decay calculations. SCALE includes unique capabilities for automated variance reduction for shielding calculations, as well as sensitivity and uncertainty analysis. SCALE's graphical user interfaces (GUIs) assist with accurate system modeling and convenient access to desired results.

This report summarizes the capabilities of SCALE 6.2, the maintenance and development activities performed during FY17, and ongoing development activities. The current public version of SCALE is SCALE 6.2.2, released in May 2017, which followed the releases of SCALE 6.2 in April 2016 and SCALE 6.2.1 in July 2016.

## Background

The SCALE code system dates back to 1969, when ORNL began providing the transportation package certification staff at the US Atomic Energy Commission (AEC) with computational support in the use of the new KENO code. KENO was used to perform criticality safety assessments with the statistical Monte Carlo method. From 1969 to 1976, AEC certification staff members relied on ORNL personnel to assist them in the correct use of codes and data for criticality, shielding, and heat transfer analyses of transportation packages. However, the certification staff learned that occasional users had difficulty in becoming proficient in performing the calculations often needed for an independent safety review. Thus, shortly after the certification staff was moved to the US Nuclear Regulatory Commission (NRC), the NRC proposed development of an easy-to-use analysis system that provided the technical capabilities of the individual modules with which they were familiar. With this proposal, the concept of SCALE as a comprehensive modeling and simulation suite for nuclear safety analysis and design was born. The NRC staff provided ORNL with the general development criteria for SCALE presented here:

1. focus on applications related to nuclear fuel facilities and package designs,
2. use well-established computer codes and data libraries,
3. design an input format for the occasional or novice user,
4. prepare standard analysis sequences (control modules) to automate the use of multiple codes (functional modules) and data to perform a system analysis, and
5. provide complete documentation and public availability.

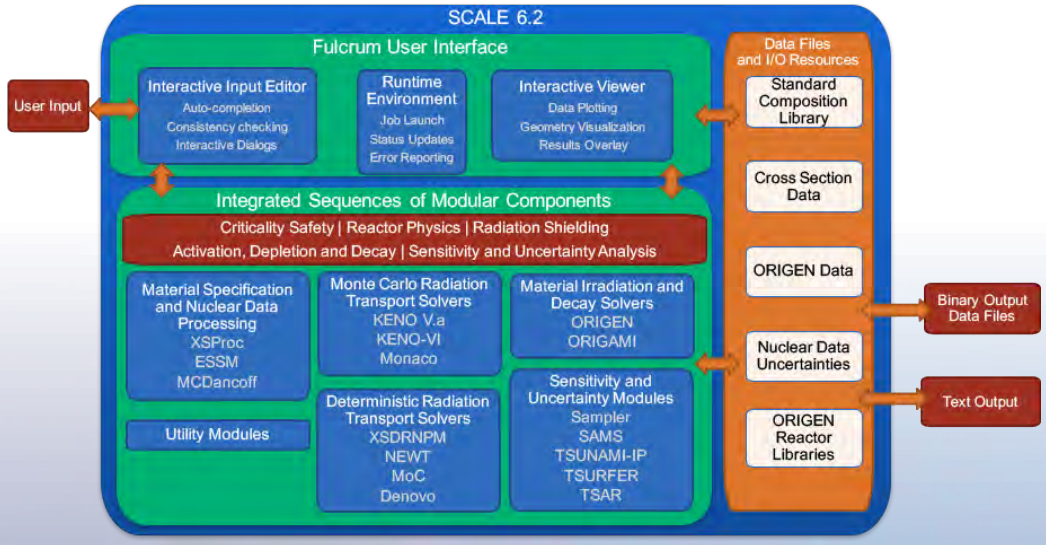
With these criteria, the ORNL staff established the framework for the SCALE system and began development. The initial version of SCALE (Version 0) was distributed in July 1980. Although the system's capabilities continue to evolve, the philosophy established with the initial release still serves as the foundation of this year's SCALE 6.2.2 update, nearly four decades later.

## SCALE Releases

| Year | Version | RSICC ID | Year | Version | RSICC ID |
|---|---|---|---|---|---|
| 1980 | SCALE 0 | CCC 288 | 1998 | SCALE 4.4 | CCC-545 |
| 1981 | SCALE 1 | CCC 424 | 2000 | SCALE 4.4a | CCC-545 |
| 1983 | SCALE 2 | CCC-450 | 2004 | SCALE 5 | CCC-725 |
| 1985 | SCALE 3 | CCC-466 | 2006 | SCALE 5.1 | CCC-732 |
| 1990 | SCALE 4 | CCC 545 | 2009 | SCALE 6.0 | CCC 750 |
| 1992 | SCALE 4.1 | CCC-545 | 2011 | SCALE 6.1 | CCC-785 |
| 1994 | SCALE 4.2 | CCC-545 | 2016 | SCALE 6.2 | CCC-834 |
| 1996 | SCALE 4.3 | CCC-545 | | | |

## Capabilities of SCALE

A primary goal of SCALE is to provide robust calculations while reducing requirements for user input. The user does not need to have extensive knowledge of the intricacies of the underlying code and data architecture. SCALE provides standardized sequences to integrate many modern and advanced capabilities into a seamless calculation that the user controls from a single input file. Additional utility modules are provided primarily for post-processing data generated from the analysis sequences for advanced studies. The user provides input for SCALE sequences in the form of text files using free-form input, with extensive use of keywords and engineering-type input requirements. SCALE's GUI helps the user create input files, visualize geometry and nuclear data, execute calculations, view output, and visualize results. A diagram showing the key capabilities of SCALE is provided in Figure 2.



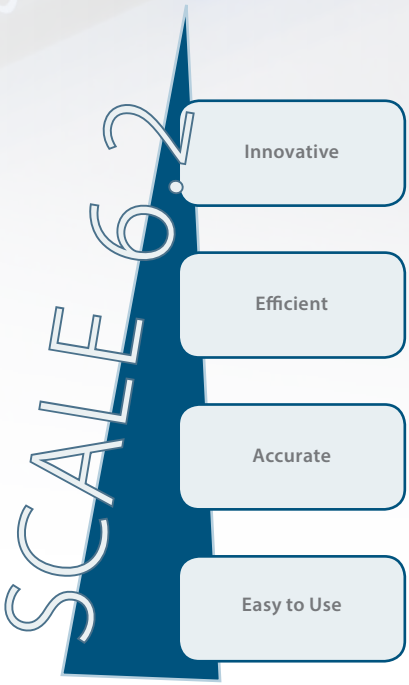




**Figure 2. SCALE capabilities**

Major SCALE capabilities and analysis areas they serve are provided in Table 1.

**Table 1. Summary of major SCALE capabilities**

| Analysis area | Modules/libraries | Analysis function(s) |
|---|---|---|
| Criticality safety | CSAS5/CSAS6 | 3D MG and CE eigenvalue Monte Carlo analysis and criticality search capability |
| | STARBUCS | Burnup credit analysis using 3D Monte Carlo |
| | Sourcerer | Hybrid 3D deterministic/Monte Carlo analysis with optimized fission source distribution |
| Reactor physics | TRITON | One-dimensional (1D) and two-dimensional (2D) general purpose lattice physics depletion calculations and generation of few-group cross section data for use in nodal core simulators<br>3D MG and CE Monte Carlo depletion analysis<br>2D eigenvalue and reaction rate sensitivity analysis |
| | Polaris | 2D streamlined LWR lattice physics depletion calculations and generation of few-group cross section data for use in nodal core simulators |
| Radiation shielding | MAVRIC | 3D CE and MG fixed-source Monte Carlo analysis with automated variance reduction |
| Activation, depletion and decay | ORIGEN | General purpose point depletion and decay code to calculate isotopic concentrations, decay heat, radiation source terms, and curie levels |
| | ORIGAMI | Simulated 2D and 3D analysis for LWR spent fuel assemblies (isotopic activation, depletion, and decay for LWR fuel assemblies) |
| | ORIGEN reactor libraries | Pregenerated burnup libraries for a variety of fuel assemblies for commercial and research reactors |
| Sensitivity and uncertainty analysis | TSUNAMI | 1D and 2D MG eigenvalue and reaction rate sensitivity analysis<br>3D MG and CE eigenvalue and reaction rate sensitivity analysis<br>Determination of experiment applicability and biases for use in code and data validation |
| | Sampler | Stochastic uncertainty quantification in results based on uncertainties in nuclear data and input parameters |

| Analysis area | Modules/libraries | Analysis function(s) |
|---|---|---|
| Material specification and cross section processing | XSProc | Temperature correction, resonance self-shielding, and flux weighting to provide problem-dependent microscopic and macroscopic MG cross section data integrated with computational sequences; also available for stand-alone analysis |
| | Standard composition library | Library used throughout SCALE that provides individual nuclides; elements with tabulated natural abundances; compounds, alloys, mixtures, and fissile solutions commonly encountered in engineering practice |
| | Monte Carlo Dancoff (MCDancoff) | 3D Monte Carlo calculation of Dancoff factors |
| Monte Carlo transport | KENO V.a/ KENO-VI | Eigenvalue Monte Carlo codes applied in many computational sequences for MG and CE neutronics analysis |
| | Monaco | Fixed source Monte Carlo code applied in the MAVRIC sequence for MG and CE analysis |
| Deterministic transport | XSDRNPM | 1D discrete ordinates transport applied for neutron, gamma, and coupled neutron/gamma analysis |
| | New ESC-Based Weighting Transport (NEWT) | 2D extended step characteristic (ESC) transport with flexible geometry applied to neutronics analysis, especially within the TRITON sequences |
| | Denovo | 3D Cartesian geometry discrete ordinates transport applied for neutron, gamma, and coupled neutron/gamma analysis, especially to generate biasing parameters within the MAVRIC and Sourcerer sequences (not generally run as stand-alone code in SCALE) |
| Nuclear data | Cross section data | Recent neutron, gamma and coupled neutron/gamma nuclear data libraries in CE and several MG structures for use in all transport modules |
| | ORIGEN data | Recent nuclear decay data, neutron reaction cross sections, energy-dependent neutron-induced fission product yields, delayed gamma ray emission data, neutron emission data, and photon yield data |
| | Covariance data | Recent uncertainties in nuclear data for neutron interaction, fission product yields, and decay data for use in TSUNAMI tools and Sampler |
| Utilities | Various | Numerous pre- and post-processing utilities for data introspection and format conversion |

## Criticality Safety

SCALE provides a suite of computational tools for criticality safety analysis that is primarily based on the KENO Monte Carlo codes for eigenvalue neutronics calculations. Two KENO variants provide identical solution capabilities with different geometry packages. KENO V.a uses a simple, efficient geometry package that is sufficient for modeling many systems of interest to criticality safety and reactor physics analysts. KENO-VI uses the SCALE Generalized Geometry Package, which provides a quadratic-based geometry system with much greater flexibility in problem modeling, but with longer runtimes. Both versions of KENO perform eigenvalue calculations for neutron transport primarily to calculate multiplication factors ($k_{eff}$) and flux distributions of fissile systems in CE and MG modes. Criticality Safety Analysis Sequence 5 (CSAS5) is typically used to access KENO V.a, and CSAS6 is typically used to access KENO-VI. The CSASs implement XSProc to process material input, and they provide a temperature- and resonance-corrected cross section library based on the physical characteristics of the problem being analyzed. If a CE cross section library is specified, no resonance processing is needed, so the CE cross sections are used directly in KENO, with temperature corrections provided as the cross sections are loaded.

CSAS5 provides search capabilities for finding desired values of $k_{eff}$ as a function of dimensions or densities. The two basic search options within CSAS5 are (1) an optimum search seeking a maximum or minimum value of $k_{eff}$ and (2) a critical search seeking a fixed value of $k_{eff}$. For CE calculations, reaction rate tallies can be requested within the CSAS input, and for MG calculations, reaction rate calculations are performed using the KENO Module for Activity-Reaction Rate Tabulation (KMART) post-processing tools. A conversion tool is provided to up-convert KENO V.a input to KENO-VI either as a direct KENO input—K5toK6—or more commonly, as a CSAS sequence—C5toC6.

The Standardized Analysis of Reactivity for Burnup Credit using SCALE (STARBUCS) performs criticality calculations for spent fuel systems employing burnup credit. STARBUCS automates the criticality safety analysis of spent fuel configurations by coupling the depletion and criticality aspects of the analysis, thereby eliminating the need to manually process the spent fuel nuclide compositions into a format compatible with criticality safety codes. For burnup-loading curve-iterative calculations, STARBUCS employs the search algorithm from CSAS5 to determine initial fuel enrichments that satisfy a convergence criterion for the calculated $k_{eff}$ value of the spent fuel configuration.

The Sourcerer sequence applies the Denovo discrete ordinates code to generate the starting fission source distribution in a KENO Monte Carlo calculation. This sequence is mostly applied to burnup credit transportation and storage analysis of as-loaded canisters of used fuel (Figure 3).

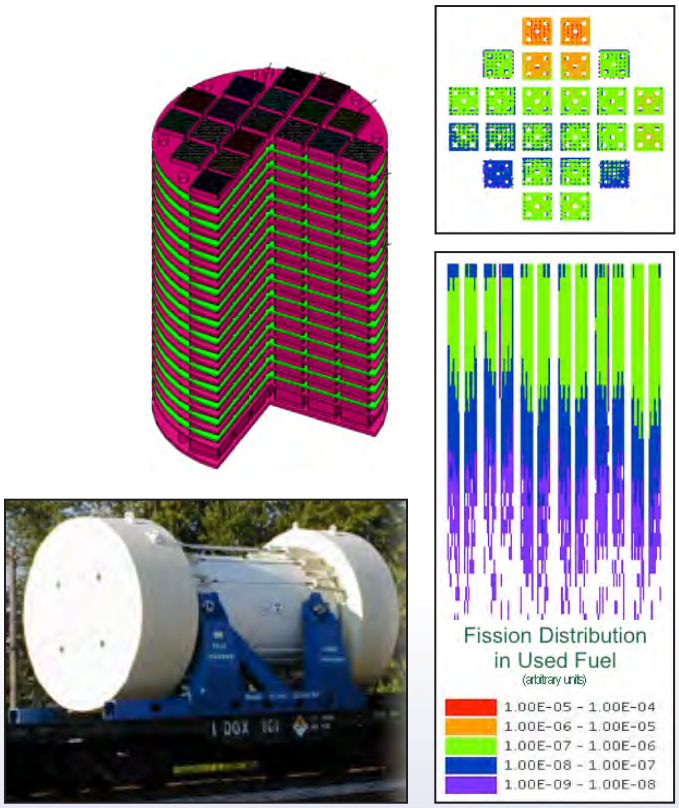



**Figure 3. Used fuel storage/ transportation cask**

## Reactor Physics

SCALE's reactor physics capabilities are integral to the NRC's licensing tools, especially when providing lattice physics data for the PARCS nodal core simulator, as shown in Figure 4.

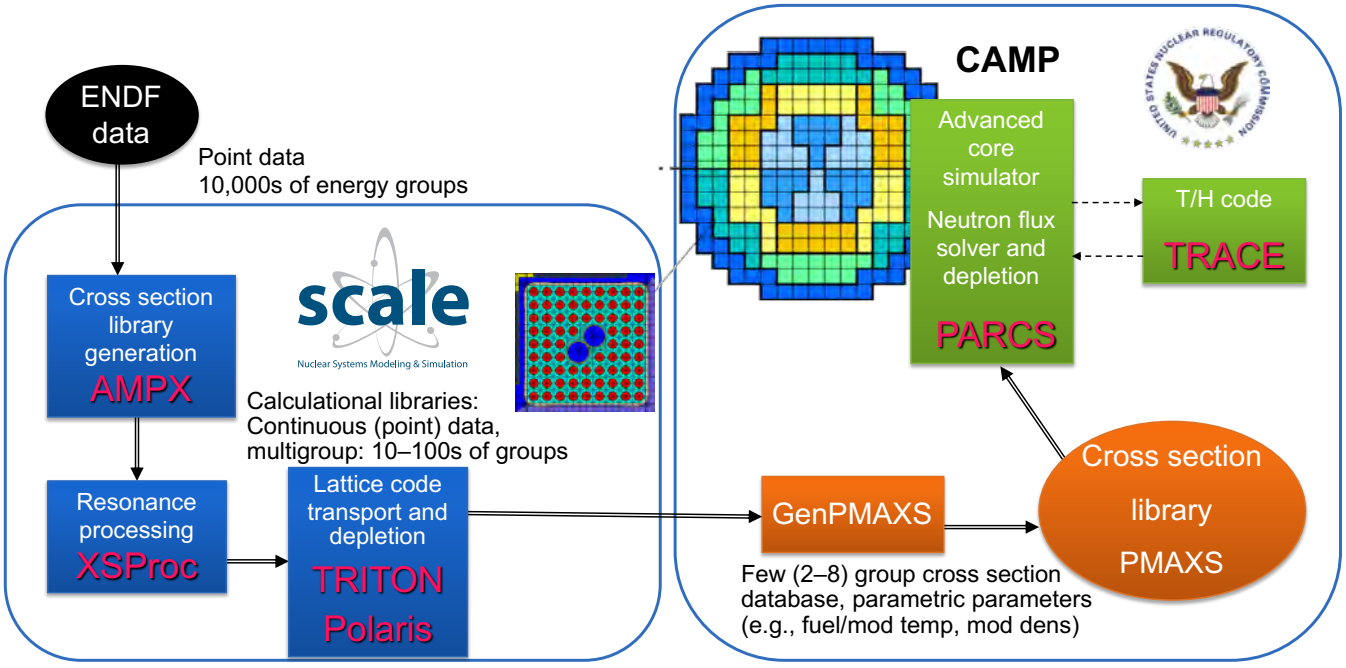



**Figure 4. Role of SCALE in NRC reactor licensing calculations**

The Transport Rigor Implemented with Time-dependent Operation for Neutronic depletion (TRITON) control module provides flexible capabilities to meet the challenges of modern reactor designs by providing one-dimensional (1D) pin-cell depletion capabilities using XSDRNPM, two-dimensional (2D) lattice physics capabilities using the NEWT flexible mesh discrete ordinates code, or three-dimensional (3D) Monte Carlo depletion using KENO V.a or KENO-VI, including CE treatment with problem-dependent temperature corrections. As shown in Figure 5, CE calculations with KENO-VI have been applied to the generation of reference power distributions for the AP-1000 reactor.

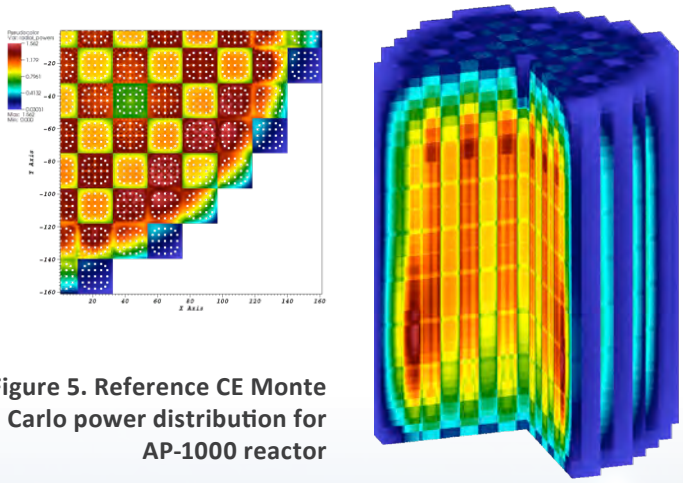


**Figure 5. Reference CE Monte Carlo power distribution for AP-1000 reactor**

## Radiation Shielding

The Monaco with Automated Variance Reduction using Importance Calculations (MAVRIC) fixed-source radiation transport sequence is designed to apply the MG and CE fixed-source Monte Carlo code, Monaco, to solve problems too challenging for standard, unbiased Monte Carlo methods. The intention of the sequence is to calculate fluxes and dose rates with low uncertainties in reasonable times, even for deep penetration problems. MAVRIC is based on the Consistent Adjoint Driven Importance Sampling (CADIS) methodology, which uses an importance map and a biased source that are derived to work together. MAVRIC generates problem-dependent cross section data, and then it automatically performs a coarse mesh 3D discrete ordinates transport calculation using Denovo to determine the adjoint flux as a function of position and energy. MAVRIC applies this information to optimize the shielding calculation in Monaco. In the Forwarded-Weighted CADIS (FW-CADIS) methodology, an additional Denovo calculation is performed to further optimize the Monaco model to obtain uniform uncertainties for multiple tally locations. Several utility modules are also provided for data introspection and conversion.

The MAVRIC tools were recently applied on behalf of the NRC to assess the site boundary dose rate for the Waste Control Specialists (WCS) Consolidated Interim Storage Facility (Figure 6). This analysis was performed based on the data provided in the publicly available license application, which includes 467 spent fuel canisters of various types.

Detailed design basis models were created for each canister using axially varying source terms from ORIGEN Assembly Isotopics (ORIGAMI) for each fuel assembly. Facility-wide dose rates are depicted in Figure 7, where the concrete pad is 243.84 m × 106.68 m, the air and soil around the concrete pad are 2,713 m × 2,576 m, the air is 959.1 m thick, and the soil is 1 m thick.

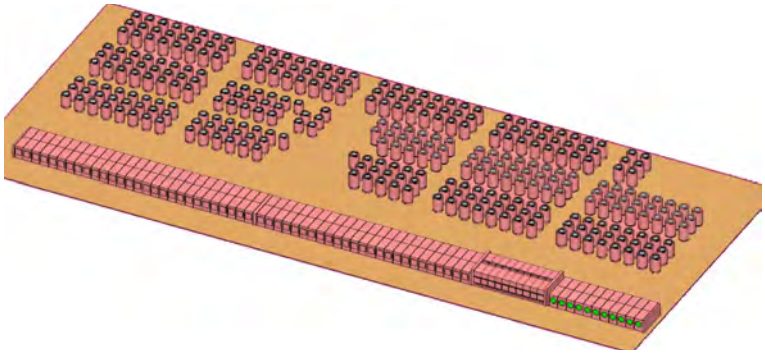


**Figure 6. SCALE MAVRIC model of WCS consolidated interim storage facility based on NRC application data**

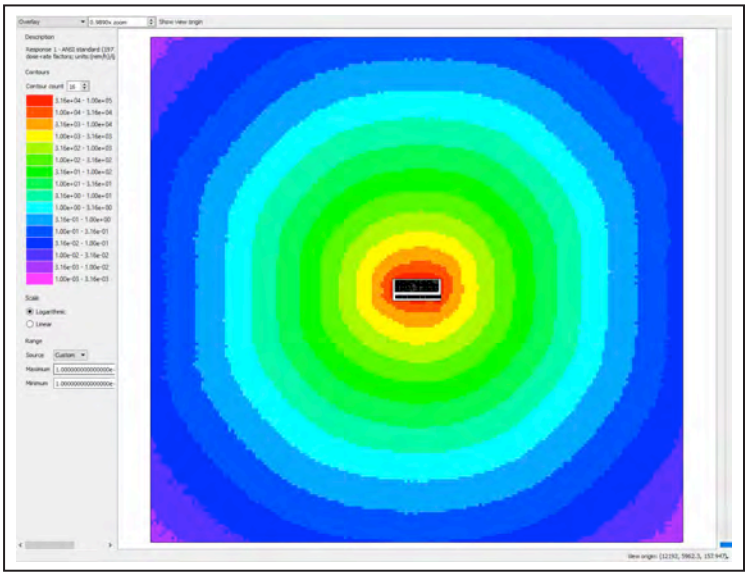


**Figure 7. Dose rate for WCS consolidated interim storage facility using detailed design basis models**

## Activation, Depletion, and Decay

The Oak Ridge Isotope Generation (ORIGEN) code calculates time-dependent concentrations, activities, and radiation source terms for a large number of isotopes that are simultaneously generated or depleted by neutron transmutation, fission, and radioactive decay. Provisions are made to include continuous nuclide feed rates and continuous chemical removal rates that can be described with rate constants for application to reprocessing or other systems that involve nuclide removal or feed. ORIGEN includes the ability to use MG cross sections processed from standard evaluated nuclear data file (ENDF)/B evaluations. Within SCALE, transport codes can be used to model user-defined systems, and the COUPLE code can be applied to calculate problem-dependent neutron-spectrum–weighted cross sections that represent conditions within any given reactor or fuel assembly. These cross sections are converted into a library to be used by ORIGEN. Time-dependent cross section libraries can be produced to reflect fuel composition variations during irradiation. An alternative sequence for depletion/decay calculations is ORIGEN-ARP, which interpolates pre-generated ORIGEN cross section libraries versus enrichment, burnup, and moderator density.

ORIGAMI computes detailed isotopic compositions for light water reactor (LWR) assemblies containing $UO_2$ fuel by using the ORIGEN code with pre-generated ORIGEN libraries for a specified assembly power distribution. The assembly may be represented as (1) a single lumped model with only an axial power distribution, (2) a square array of fuel pins with variable pin powers, or (3) an axial distribution. Multiple cycles with varying burn times and down times may be used. ORIGAMI produces files containing SCALE and Monte Carlo N-Particle (MCNP) composition input for material in the burnup distribution, files containing decay heat for use in thermal analysis, and energy-dependent radioactive source for use in shielding calculations (Figure 8).

A series of 1,470 pre-generated burnup libraries for use in ORIGEN and ORIGAMI is provided with SCALE for 61 fuel assemblies for commercial and research reactors.

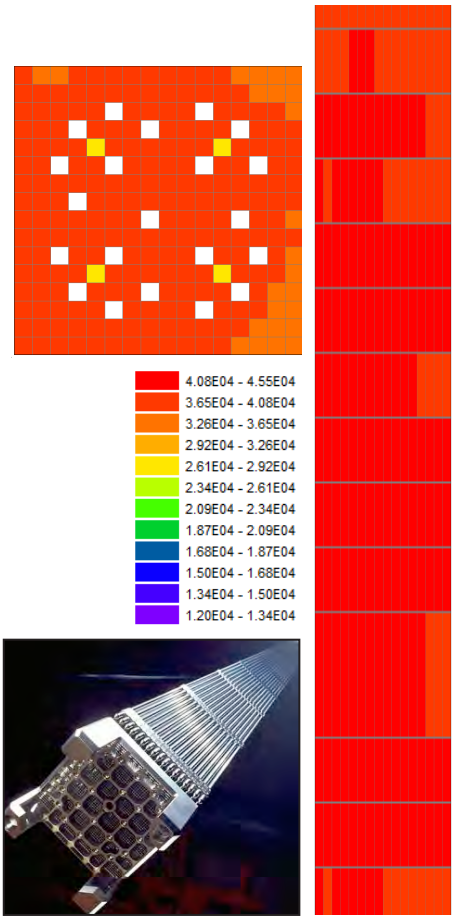



**Figure 8. Pin-by-pin burnup and radioactive source terms**

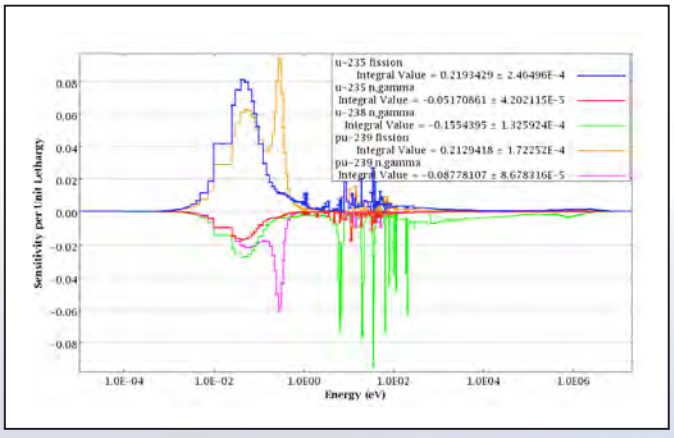



**Figure 9. Sensitivity of $k_{eff}$ to cross section data**

## Sensitivity and Uncertainty Analysis

SCALE provides a suite of computational tools for sensitivity and uncertainty analysis to (1) identify important processes in safety analysis and design, (2) provide a quantifiable basis for neutronics validation for criticality safety and reactor physics analysis based on similarity assessment, and (3) quantify the effects of uncertainties in nuclear data and physical parameters for safety analysis.

The Tools for Sensitivity and Uncertainty Analysis Methodology Implementation (TSUNAMI)-1D, TSUNAMI-2D and TSUNAMI-3D analysis sequences compute the sensitivity of $k_{eff}$ and reaction rates to energy-dependent cross section data for each reaction of each nuclide in a system model (Figure 9).

The 1D transport calculations are performed with XSDRNPM, the 2D transport calculations are performed using NEWT, and the 3D calculations are performed with KENO V.a or KENO-VI. The Monte Carlo capabilities of TSUNAMI-3D provide for sensitivity/uncertainty (S/U) analysis from either CE or MG neutron transport, where the deterministic capabilities of TSUNAMI-1D and TSUNAMI-2D only operate in MG mode. The Sensitivity Analysis Module for SCALE (SAMS) is applied within each analysis sequence to provide the requested S/U data. Whether performing a CE or MG calculation, energy-dependent sensitivity data are stored in group form in a sensitivity data file (SDF) for subsequent analysis. These sequences use the energy-dependent cross section covariance data to compute the uncertainty in the response value due to the cross section covariance data.

The Tool for Sensitivity Analysis of Reactivity Responses (TSAR) computes the sensitivity of the reactivity change between two $k_{eff}$ calculations using SDFs from TSUNAMI-1D, TSUNAMI-2D, and/or TSUNAMI-3D. TSAR also computes the uncertainty in the reactivity difference due to the cross section covariance data.

TSUNAMI Indices and Parameters (TSUNAMI-IP) computes correlation coefficients that determine the amount of shared uncertainty between each target application and each benchmark experiment considered in the analysis. TSUNAMI-IP offers a wide range of options for more detailed assessment of system-to-system similarity. Additionally, TSUNAMI-IP can generate input for the Upper Subcritical Limit Statistical Software (USLSTATS) trending analysis and compute a penalty or additional margin needed for the gap analysis.

Tool for S/U Analysis of Response Functions Using Experimental Results (TSURFER) is a tool that predicts bias and bias uncertainty. TSURFER implements the generalized linear least-squares (GLLS) approach to data assimilation and cross section data adjustment that also uses the SDFs generated from TSUNAMI-1D, -2D, -3D, or TSAR. The data adjustments produced by TSURFER are not used to produce adjusted cross section data libraries for subsequent use; rather, they are used only to predict biases in application systems.

Extensible SCALE Intelligent Text Editor (ExSITE) is a GUI that facilitates analysis with TSUNAMI-IP, TSURFER, TSAR, and USLSTATS. The Validation, Interpretation and Bias Estimation (VIBE) interface is applied to examine SDF files, create sets of benchmark experiments for subsequent analysis, and gather additional information about each benchmark experiment.

Sampler is a super-sequence that performs general uncertainty analysis by stochastically sampling uncertain parameters that can be applied to any type of SCALE calculation, propagating uncertainties throughout a computational sequence. Sampler treats uncertainties from two sources: (1) nuclear data and (2) input parameters. Sampler generates the uncertainty in any result generated by any computational sequence through stochastic means by repeating numerous passes through the computational sequence, each with a randomly perturbed sample of the requested uncertain quantities (Figure 10).

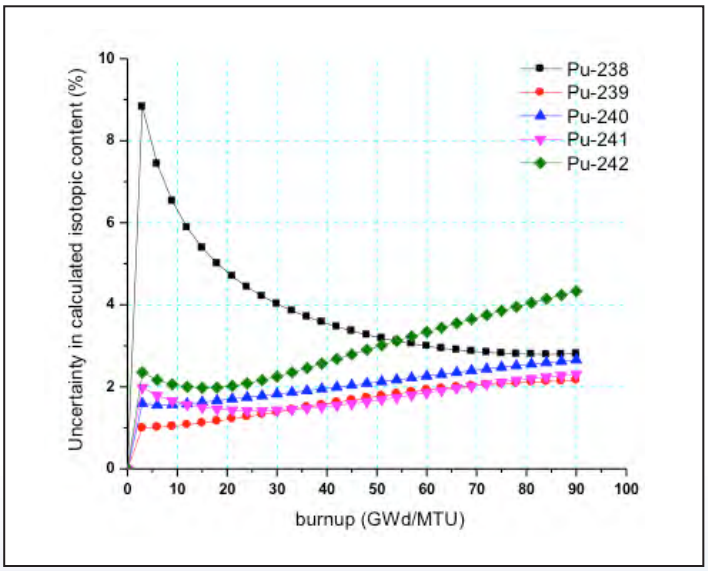



**Figure 10. Uncertainty in plutonium isotopics in LWR depletion**

### Material Specification and Cross Section Processing

Cross Section Processing (XSProc) provides material input and MG cross section preparation for most SCALE sequences. XSProc allows users to specify materials in the model through easily remembered, easily recognizable keywords associated with mixtures, elements, nuclides, and fissile solutions provided in the SCALE Standard Composition Library. For MG calculations, XSProc provides cross section temperature correction and resonance self-shielding, as well as energy group collapse and spatial homogenization for systems that can be represented in unit cell input data as infinite media, finite 1D systems, or repeating structures of 1D systems such as uniform arrays of fuel units. Improved resonance self-shielding treatment for nonuniform lattices can be achieved through the use of the Monte Carlo Dancoff (MCDancoff) code that generates Dancoff factors for generalized 3D geometries for subsequent use in XSProc. Cross sections are generated on a microscopic and/or macroscopic basis as needed. Although XSProc is most often used as part of an integrated sequence, it can be run without subsequent calculations to generate problem-dependent MG data for use in other tools.

### Monte Carlo Transport

Monte Carlo transport is discussed throughout the previous sections.

### Deterministic Transport

Deterministic transport is discussed throughout the previous sections.

### Nuclear Data

The cross section data provided with SCALE include comprehensive CE neutron and coupled neutron-gamma data based on ENDF/B-VII.0 and ENDF/B-VII.1 (Figure 11).

These data have been generated with the AMPX codes. The MG data are provided in several energy-group structures optimized for different application areas, including criticality safety, lattice physics, and shielding analysis. The comprehensive ORIGEN data libraries are based on ENDF/B-VII.1 and recent joint evaluated fission and fusion file (JEFF) evaluations, and they include nuclear decay data, neutron reaction cross sections, neutron-induced fission product yields, delayed gamma ray emission data, and neutron emission data for over 2,200 nuclides. The photon yield data libraries are based on the most recent evaluated nuclear structure data file (ENSDF) nuclear structure evaluations. The libraries used by ORIGEN can be coupled directly with detailed, problem-dependent physics calculations to obtain self-shielded, problem-dependent cross sections based on the most recent evaluations. There are no limitations on compositions or energy spectra. SCALE also contains a comprehensive library of neutron cross section covariance data for neutron interactions and fission product yields, as well as decay data for use in S/U analysis with TSUNAMI codes and Sampler.

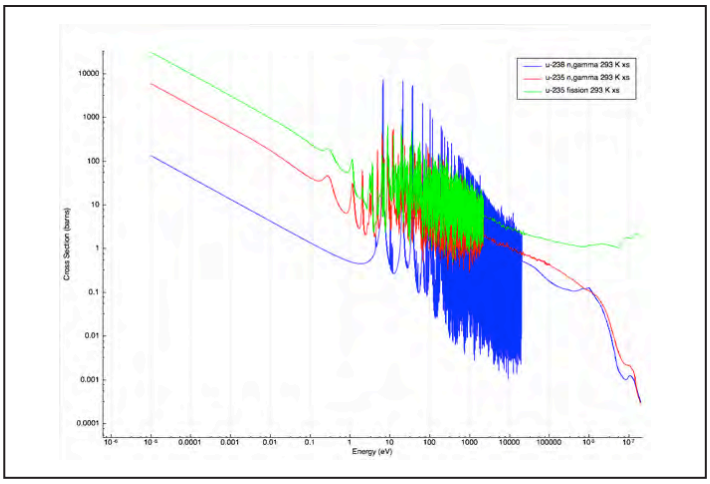



**Figure 11. Nuclear data generated with AMPX**

The full suite of AMPX codes for generating MG and CE neutron, gamma, and coupled neutron/gamma libraries and covariance data are also included in the SCALE distribution. This allows users to create their own nuclear data libraries, drawing from sources of data and energy group structures other than those provided with SCALE.

# Utilities

## Graphical User Interfaces

Fulcrum is a cross platform GUI designed to create, edit, validate and visualize SCALE input, output, and data files (Figure 12).

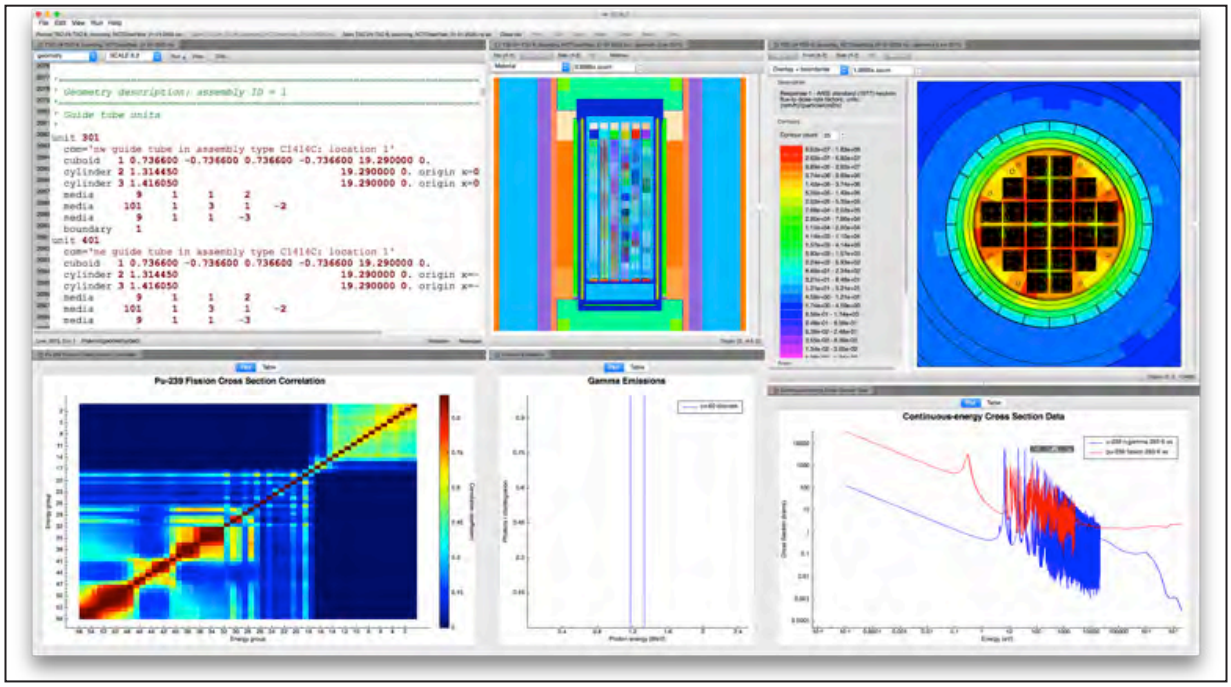



**Figure 12. Fulcrum GUI**

Fulcrum provides input editing and navigation, interactive geometry visualization for KENO V.a, KENO-VI, and NEWT, job execution, overlay of mesh results within a geometry view, and plotting of data from most SCALE file formats. An error checking parser interactively identifies poorly constructed input with spelling errors or data entry omissions for all SCALE sequences. The Hierarchical Input Validation Engine (HIVE) will identify allowed data ranges and interdependencies in the input and report inconsistencies to the user. Fulcrum will interactively process standard composition data to produce a mixing table, list expanded input aliases for review, provide an internal listing of input as is required for Sampler material and geometry perturbation analysis, and launch the SCALE sample problems. The layout of panels in Fulcrum is highly configurable to accommodate many user preferences.

ORIGAMI Automator, a GUI integrated with Fulcrum, facilitates the quantification of isotopics as a function of time for a large set of fuel assemblies, such as the complete inventory of a spent fuel pool. This tool was developed to support the NRC in severe accident analyses, but it can be adapted to many other uses.

Additional user interfaces include the KENO3D interactive visualization program for Windows for solid-body rendering of KENO geometry models, as well as the previously mentioned ExSITE and VIBE interfaces for S/U analysis. Several SCALE modules provide HTML-formatted output, in addition to the standard text output, to allow for convenient navigation using the most common web browsers through the computed results. Interactive color-coded output and integrated data visualization tools are key features.

## SCALE Distribution

The SCALE code system continues to provide capabilities for the analysis needs of the multi-agency programs supporting SCALE. The system continues to grow in popularity with domestic and international users. Since 2004, 12,893 copies of SCALE have been distributed to 8,204 unique users in 58 nations (Figure 13).

Since the April 2016 release of SCALE 6.2, distribution centers have issued licenses for 3,119 copies of this latest SCALE version, including 934 distributions to new users who had not previously licensed any version of SCALE. The distribution of SCALE licenses over time is shown in Figure 14.

As seen in Figure 14, the growth in the rate of distribution of SCALE is observed as the slope of the distribution plot, with a marked increase after the release of SCALE 6.2.

The distribution of SCALE to end users is subject to US export control regulations, and each user must be individually licensed through an authorized distribution center. SCALE licenses are primarily issued through the Radiation Safety Information Computational Center (RSICC) at ORNL, with mirrors at the Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Data Bank in France and the Research Organization for Information Science and Technology (RIST) in Japan. Any license fees collected for the distribution of SCALE are retained by these organizations to offset the costs of background checks and media duplication, and no part of the license revenue is used to support SCALE activities.

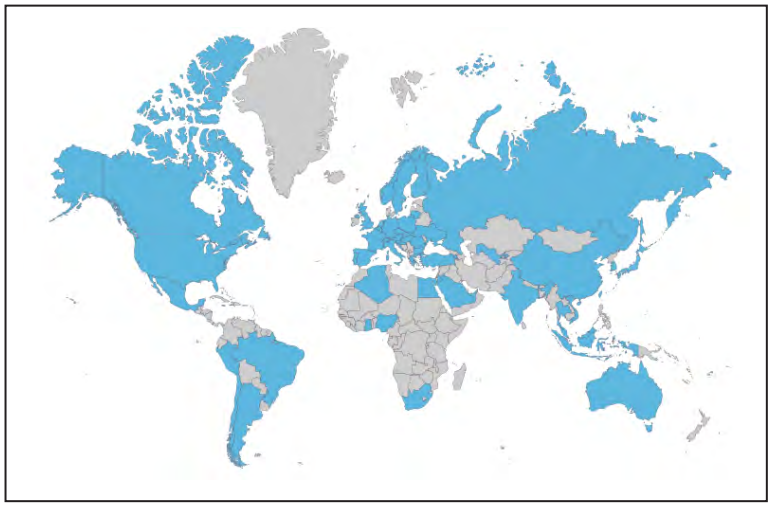


**Figure 13. Nations with licensed SCALE users**

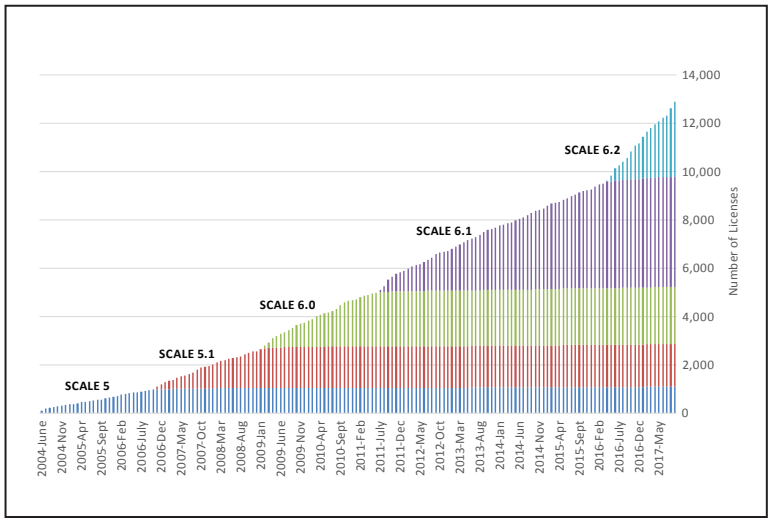



**Figure 14. Number of licenses issued for SCALE 5–6.2**

## Training Courses and Workshops

SCALE training courses and workshops continue to be popular with users. Training is provided by developers and expert users from the SCALE team. Courses provide a review of theory, descriptions of software capabilities and limitations, and hands-on experience running problems of varying levels of complexity. In FY17, 9 weeklong courses were presented at ORNL, the OECD/NEA Data Bank, NRC headquarters, National Research Nuclear University Moscow Engineering Physics Institute (MEPhI) in Moscow, Russia, and at user facilities. Additionally, workshops were presented at conferences and universities. In total, SCALE training was presented to more than 110 participants from 14 nations. The training courses are funded through user registration fees and are self-sustaining. Site-specific courses can be customized to meet the needs of many teams. Figures 15, 16, 17, and 18 show attendees from various SCALE training courses.

**Figure 15. SCALE Criticality Safety and Radiation Shielding Course**
ORNL, Oak Ridge, TN, February 2017


**Figure 16. Site-specific SCALE Criticality Safety Calculations Course**
Areva, Lynchburg, VA, May 2017

**Figure 17. Site-specific SCALE and UNF-ST&DARDS Training**
"Spent Fuel Characterization and Decay Heat," Svensk Kärnbränslehantering (SKB), Swedish Nuclear Fuel and Waste Management Company, Stockholm, Sweden, June 2017


**Figure 18. OECD/NEA SCALE ORIGEN Training Course**
Moscow Engineering Physics Institute (MEPhI), Moscow, Russia, October 2017

Visit the SCALE training website for more information: https://www.ornl.gov/scale/scale-training.

## SCALE Users' Group Workshop

The first SCALE Users' Group Workshop was held September 26–28, 2017, with 130 registered participants from the NRC, the US Department of Energy (DOE), national laboratories, industry, and academia. The opening plenary session featured keynote speakers Drew Barto (NRC), who described the 41-year history of the SCALE Code System for the criticality, shielding, and source terms analysis of spent fuel, as well as Larry Wetzel from BWX Technologies, who described 30 years of applying SCALE for criticality safety assessment and criticality accident alarm analysis.

**Figure 19. Participants in the 2017 SCALE Users' Group Workshop**


**Figure 20. Brad Rearden introduces SCALE**

**Figure 21. Drew Barto of the NRC delivers a keynote address**

***Technical sessions were provided on the following topics:***

- Criticality Safety
- Depletion and Source Terms
- Nuclear Data
- Radiation Shielding
- Reactor Physics
- Sensitivity and Uncertainty Analysis

***A panel discussion was held on the 40-year heritage of SCALE, featuring the following esteemed speakers:***

- Mike Westfall, ORNL (ret.), originator of SCALE, 1976
- Lester Petrie, ORNL (ret.), principal developer and architect of SCALE, 1976–2016
- Cecil Parks, ORNL, SCALE project leader, 1979–1994
- Steve Bowman, ORNL, SCALE project leader, 1995–2009
- Brad Rearden (moderator), ORNL, manager, SCALE Code System, 2009–present

***Tutorial sessions were provided on the following topics:***

- ORIGAMI Spent Fuel Characterization
- TSUNAMI Sensitivity/Uncertainty Analysis
- Polaris Lattice Physics Calculations
- Sampler Uncertainty Quantification

***Technical tours of the following ORNL facilities were provided:***

- High Flux Isotope Reactor
- ORNL Spent Fuel Experimental Facility
- Historical ORNL Graphite Reactor
- National Center for Computational Sciences


**Figure 22. Larry Wetzel, BWX Technologies, delivers a keynote address**


**Figure 23. Participants in the SCALE Heritage Panel** ***(Left to right)*** Brad Rearden, Steve Bowman, Cecil Parks, Lester Petrie, and Mike Westfall

**The full agenda with links to the presentations is available at:**
https://www.ornl.gov/scale/scale/2017-scale-users-group-workshop

**A series of photos from the workshop are available at:**
https://www.ornl.gov/scale/scale/2017-scale-users-group-workshop-photos 4.3.

## SCALE Maintenance and Development Activities

The primary goal of the SCALE maintenance and development activities is to ensure that the SCALE code system continues to meet the needs of sponsors and users by providing verified, validated results and remaining current with state-of-the-art computing technology.

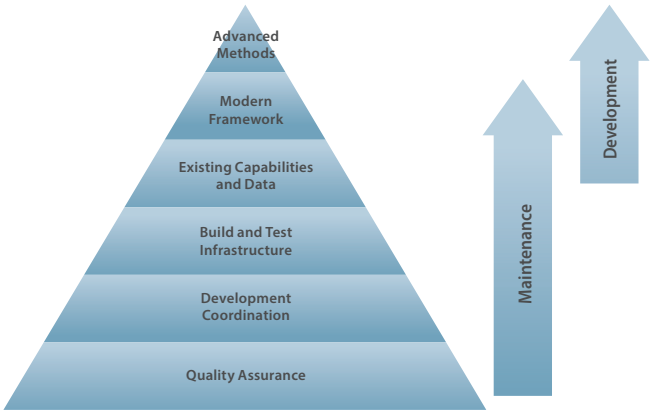



**Figure 24. SCALE activities diagram**

SCALE maintenance activities provide an essential foundation for all activities related to reliable development and use of SCALE. Maintenance activities include quality assurance (QA), development coordination, build-and-test infrastructure, and support for all existing capabilities and features. Recently, the SCALE team has focused efforts on infrastructure modernization by reviewing and incrementally updating components and procedures which had evolved over a 40-year period, applying modern software development practices and QA standards. An essential component of this ongoing activity is the development of a modern framework for SCALE analysis which enables rapid development of advanced methods, parallel operation, and easy integration of SCALE tools with other analysis packages.

Development activities involve major enhancements and introduction of advanced methods to existing modules, as well as development of new modules, data libraries, and user interfaces. These activities employ current computing and programming techniques, building on the modernized framework of the overall SCALE code system, as illustrated in Figure 24.

## Quality Assurance

Activities classified as maintenance begin with the establishment of the QA framework that is applied to all SCALE codes and data. As depicted in Figure 25, the SCALE QA program is kept current with international consensus standards (ISO-9001-2008, ASME NQA-1), DOE orders (DOE 414.1D), NRC guidelines (NUREG/BR-0167) and the ORNL Standards-Based Management System. A review of the SCALE QA plan is performed annually by the ORNL RNSD Software QA Board. The SCALE QA plan continues to be viewed as a model plan both inside and outside ORNL.

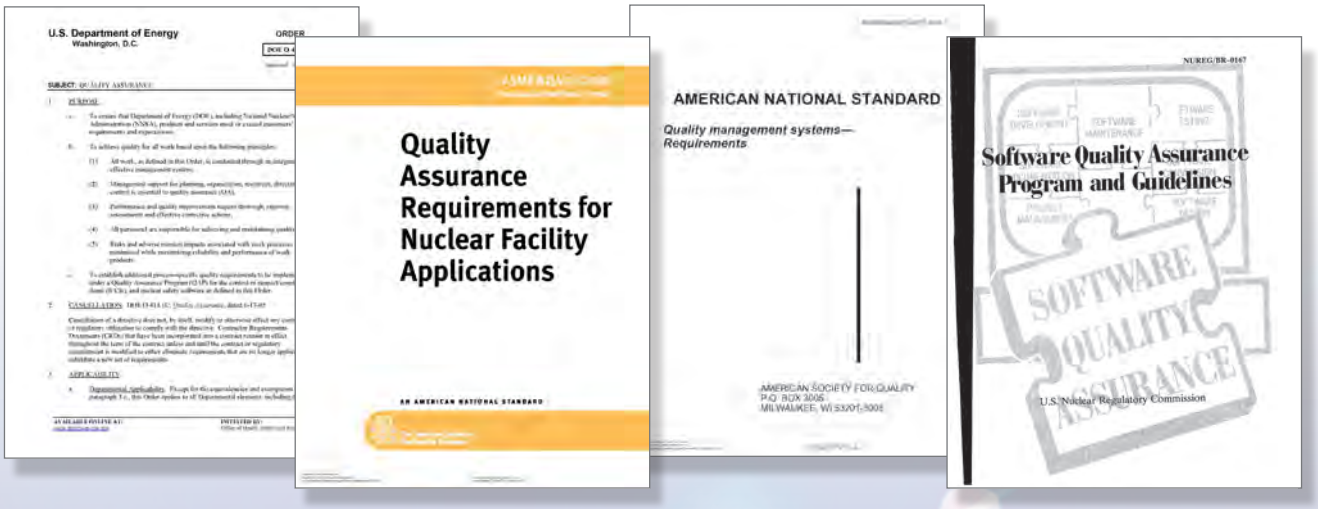



**Figure 25. Reference documents for SCALE QA Program**

## Development Coordination

At ORNL, the SCALE code system is developed, deployed, and supported by dozens of staff members throughout RNSD. All SCALE activities are coordinated to facilitate consistency throughout the project, especially in the application of QA, development practices, and testing strategies. The SCALE Leadership Team consists of the SCALE manager, deputy manager, line managers, program managers, and developers as designated by the SCALE manager. The Leadership Team meets regularly to discuss the current status and to make programmatic and managerial decisions regarding SCALE.

SCALE teams are organized to coordinate work activities within given areas as shown in Figure 26. Each team meets independently to plan and coordinate work activities. The teams are organized so that members from different work areas are included on multiple teams to improve communication and coordination between work areas. Although the activities of most teams are supported by targeted development tasks, coordination of the teams and review of their work is supported as a maintenance activity. A weekly forum for developers and users is conducted to maintain a productive dialog and collaborative mission among developers, users, and managers throughout ORNL.

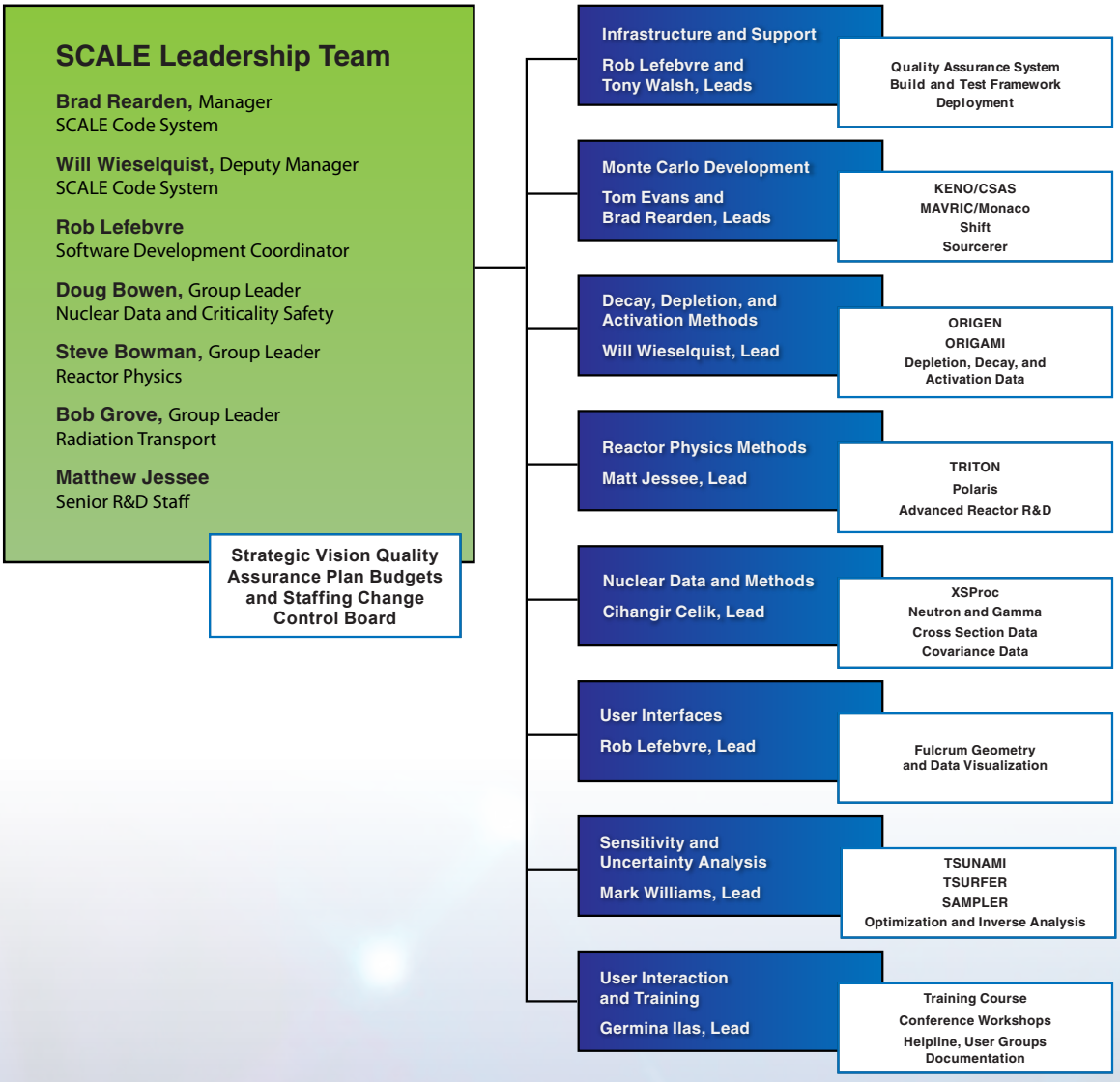



**Figure 26. SCALE team structure**

**Figure 27. SCALE 6.2 Team – May 2016**
***(Left to right)*** Ahmed Ibrahim, Germina Ilas, Brandon Langley, Andrew Holcomb, Shane Hart, Cihangir Celik, Seth Johnson, Matthew Jessee, Kevin Clarno, Adam Thompson, Bob Grove, Rob Lefebvre, Greg Davidson, Charles Daily, Alan Icenhour, Barbara Snow, Brian Ade, Brad Rearden, Ben Betzler, B. J. Marshall, Kursat Bekar, Will Wieselquist, Mark Baird, Mark Williams, Georgeta Radulescu, Ron Ellis, Thomas Miller, Dan Ilas, Elizabeth Jones, Cecil Parks, Sheila Walker, Teresa Moore, Marsha Henley, Sandra Poarch, Lester Petrie

In addition to the Leadership Team personnel and the team leads shown in Figure 26, almost 50 team members (Table 2, Figure 27) contribute to SCALE on a routine or occasional basis.

### Table 2. SCALE team members

- Brian J. Ade
- Seth R. Johnson
- Lindsey D. Aloisi
- Kang Seog Kim
- Goran Arbanas
- Brandon R. Langley
- Kaushik Banerjee
- William J. Marshall
- Kursat B. Bekar
- Ugur Mertyurek
- Benjamin R. Betzler
- Thomas M. Miller
- Keith C. Bledsoe
- Tara M. Pandya
- Friederike Bostelmann
- Douglas E. Peplow
- Justin B. Clarity
- Christopher M. Perfetti
- Charles R. Daily
- Joshua L. Peterson-Droogh
- Gregory G. Davidson
- Marco T. Pigni
- Ronald J. Ellis
- Sandra J. Poarch
- Thomas M. Evans
- Georgeta Radulescu
- Ian C. Gauld
- Rose B. Raney
- Cole A. Gentry
- Joel M. Risner
- Andrew T. Godfrey
- Diane J. Sams
- Steven P. Hamilton
- John M. Scaglione
- Shane W. Hart
- Steven E. Skutnik
- Marsha D. Henley
- Vladimir Sobes
- Andrew M. Holcomb
- Adam B. Thompson
- Jianwei Hu
- Sheila Y. Walker
- Germina Ilas
- Tony Walsh
- Dan Ilas
- Dorothea Wiarda

### Build and Test System

The success of any ongoing software project requires routine compilation and testing of software and data, along with providing continual support for the latest hardware and compilers. For SCALE, this foundation is provided as a maintenance activity.

After each incremental update to the source code, a suite of over 2,000 test cases is run on each of dozens of computer platform configurations, including Linux, Mac, and Windows with different compilers and compiler options. This rigorous testing is performed dozens of times each day, resulting in the quantification of performance with approximately 150,000 tests per day. The results of the tests and the associated changes are reported to an internal website, the SCALE Dashboard. All developers can review the Dashboard to monitor the performance of numerous SCALE features on different platforms with different compilers using a pass/fail metric, eliminating the need for users to configure and run all tests themselves. In FY17, the number of systems continually building and testing SCALE was increased to obtain even finer quantification of the impact of individual changes. The hardware listed in Table 3, which consists of 436 processors and 1,672 GB RAM, is dedicated to running automated SCALE testing 24 hours a day, 7 days a week.

All changes to the SCALE source code are recorded and versioned in a repository system. This system streamlines the development process, facilitates easier collaboration between developers, and provides easier quantification of changes to improve the QA review process.

**Table 3. SCALE continuous integration hardware**

| Platform | Hardware |
|---|---|
| **Linux** | • 8 cluster nodes each with 8 processors and 32 GB RAM<br>• 1 dedicated computer with 64 cores and 256 GB RAM |
| **Mac** | • 3 Mac Pro computers each with 16 processors and 20 GB RAM<br>• 2 Mac Pro computers each with 24 processors and 64 GB RAM |
| **Windows** | • 2 Windows 7 computers each with 8 processors and 16 GB RAM<br>• 1 Windows 7 computer with 16 processors and 12 GB RAM<br>• 1 Windows 2012 Server with 32 processors and 128 GB RAM<br>• 2 Windows 2012 R2 Servers with 44 processors and 128 GB RAM<br>• 3 Windows 2016 Servers with 20 processors and 256 GB RAM |

### Existing Capabilities and Data

SCALE 6.2 consists of approximately 2,000,000 lines of source code for 77 executable modules, 43 GB of nuclear data in approximately 9,000 files, and more than 2,700 pages of user documentation. With 8,000 licensed users of SCALE 5–6.1 in 58 nations, extensive communication is required. The SCALE team provides ongoing support to users. The team addressed approximately 700 inquiries during FY17 through scalehelp@ornl.gov email. Additionally, an online discussion forum is available for SCALE users to post and review issues as a community (https://groups.google.com/forum/#!forum/scale-users-group). User communication in the form of website postings and newsletters is also provided.

Targeted development tasks generate dozens of new capabilities each year, and at the end of each development task, enhancements and user support for these features, additional testing and bug fixes, and integration of new features with existing features are supported as maintenance activities.

### Modern Framework

The foundation of modern SCALE is a modular C++ software framework for efficient operation that also enables parallel computations. Individual computational components communicate through an efficient in-memory application programming interface (API) instead of slow file input/output (I/O) to the hard disk used in earlier releases. APIs also enhance communication between components by allowing for clear requirements on the data I/O of each modular component. Each capability that provides an API is referred to as a module. Where internal tests are applied to ensure that data passed through the API meet all requirements of the module, linkages with other modules can be efficiently modified without disrupting any part of the overall system. The concept of individual functional modules as stand-alone executable programs will diminish as individual physics capabilities are consolidated into a unified, executable program capable of performing all SCALE functionality within an efficient parallel infrastructure. Additionally, the modern API-based framework enables the development of a modern GUI that implements the same modules used for computational analysis, eliminating the need to develop and maintain a feature twice, once for computational use and again for the GUI.

### Advanced Methods

Advanced methods are developed as targeted tasks unless an incremental advancement is required to correct a discrepancy or enhance an existing feature for compatibility with a new feature. However, once an advanced method is complete, QA and maintenance activities are usually required to continue to provide support for that method. Thus, as new features are integrated into SCALE, the amount of maintenance required is incrementally increased pending removal of deprecated features. While many advanced methods were introduced with SCALE 6.2, the SCALE modernization plan details additional advancements, culminating in the fully modernized SCALE 7. A key aspect of SCALE 7 is the replacement of the KENO and Monaco Monte Carlo codes with the advanced and integrated Shift Monte Carlo code.

### Ongoing Development

The SCALE team is dedicated to supporting the advanced features provided in SCALE 6.2 and is working to extend these capabilities for additional types of analysis, such as very large, complex interim storage sites for used fuel; analysis of advanced reactors including molten salt reactors (MSRs), fluoride-salt-cooled high-temperature reactors (FHRs), high-temperature gas-cooled reactors (HTGRs) and sodium-cooled fast reactors (SFRs); analysis of advanced technology fuels; and advanced validation approaches for new or challenging systems. Existing capabilities will continue to be improved through additional efficiency and accuracy gains, as well as additional enhancements to the user interface. The development of many of these capabilities is in progress now to be available with the release of SCALE 6.3. The nuclear data generated by the AMPX tools for all SCALE CE, MG, activation/decay, and covariance libraries will continue to be improved through an iterative development cycle that includes increased testing under the QA plan and timely deployment of the most current nuclear data libraries. Modernization plans for SCALE and AMPX include increased synchronization of development activities and shared resources between these two projects. Several specific initiatives are described in more detail below.

### Integration of the Shift Monte Carlo Code

It is desirable to position SCALE for the future with an extensive reprogramming of existing capabilities to improve run-time performance and solution fidelity. The most significant changes planned for the future are the ability to execute SCALE in parallel on multiple central processing units (CPUs), whether on desktops, workstation clusters, or high-performance supercomputers. This strategy includes the integration of the Shift Monte Carlo code, which is capable of excellent parallel scaling on leadership class computing architectures such as ORNL's TITAN machine, which includes approximately 300,000 processors. However, the integration of Shift is also important for the desktop and workstation user, as the modern and efficient design of Shift provides single processor calculations that are 2–4 times faster than KENO-VI. The Shift Monte Carlo code leverages many SCALE modernization capabilities such as the input processing, nuclear data resources, and modules for CE and MG physics, modular geometry, sensitivity/uncertainty analysis, and depletion (Figure 28). The staged migration and testing of individual SCALE capabilities in the modern framework ensures robust development, testing, and deployment of this new tool. The long-term modernization plan includes full modularity and parallelization in SCALE 7 including the integration of the Shift Monte Carlo code.

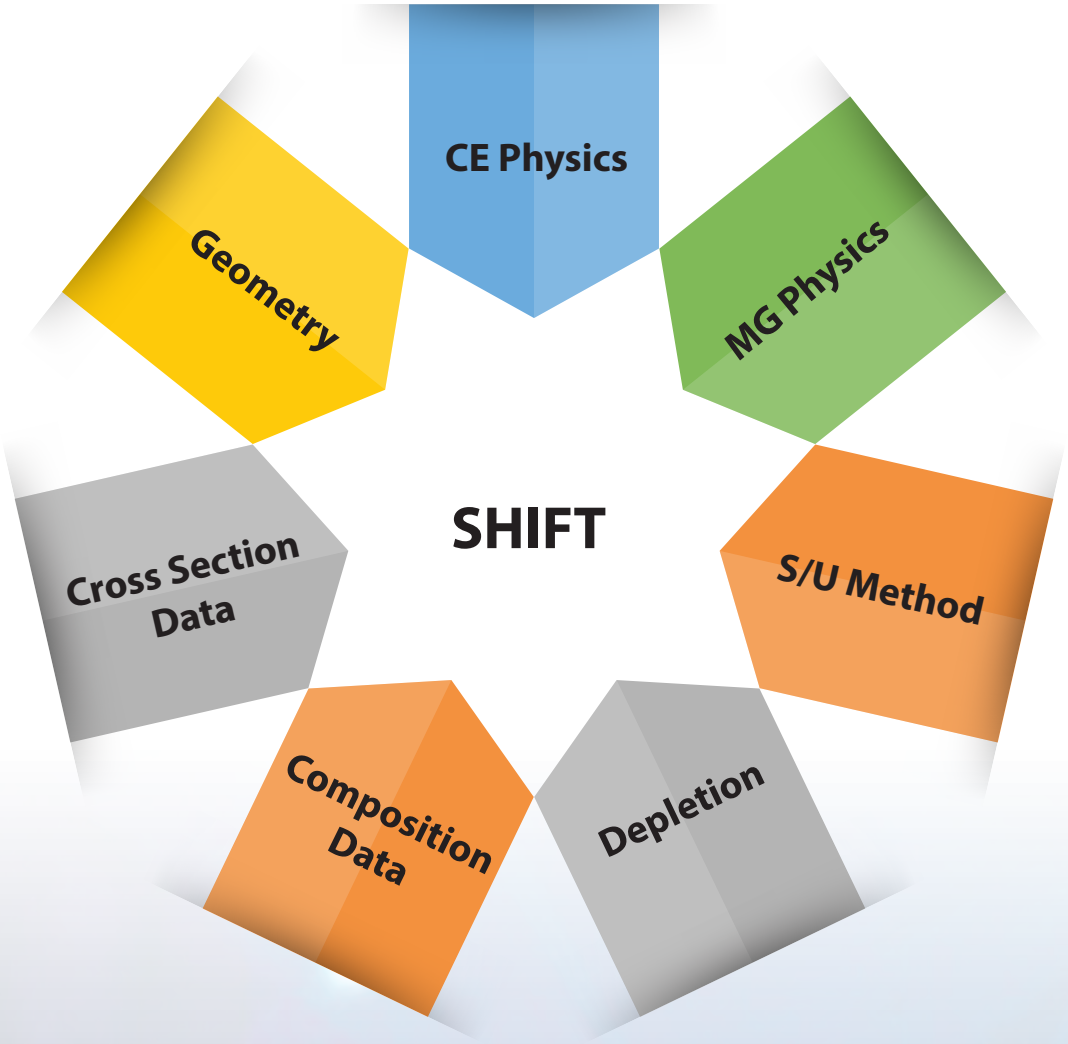



**Figure 28. Advanced Monte Carlo methods with Shift**

## SCALE 6.3 Development for Advanced Reactors and Advanced Technology Fuels

Several projects are under way in FY18 to develop new code and data capabilities in SCALE 6.3 for modeling advanced reactors and advanced technology fuels (ATFs), sometimes referred to as accident-tolerant fuels. Historically, many of SCALE's capabilities have been developed and applied to LWR fuel applications, and the NRC is sponsoring the extension of these capabilities to support the regulatory review of advanced concepts. Most of the recent enhancements focus on the Polaris lattice physics code and the high performance, massively parallel Monte Carlo code Shift. In addition, new MG cross section libraries are being developed for non-LWR applications, and the integration of SCALE with other NRC licensing tools is being improved.

### *Lattice Physics for Advanced Concepts*

For Polaris, the non-LWR capabilities under development include hexagonal geometry support to simulate HTGRs, SFRs, and prismatic assembly designs. Additionally, a double-heterogeneity modeling capability will be added to support HTGR prismatic analysis and ATF based on TRISO-particle fuel forms. For MSRs, a time-dependent chemical processing model and delayed neutron precursor drift model are being integrated into Polaris to allow time-dependent modeling of the molten salt fuel. These two models are already being implemented in TRITON for SCALE 6.3 for MSR analysis (Figure 29). Another new feature is defining the branch and history requirements in Polaris for advanced reactor modeling with PARCS or other nodal core simulators.

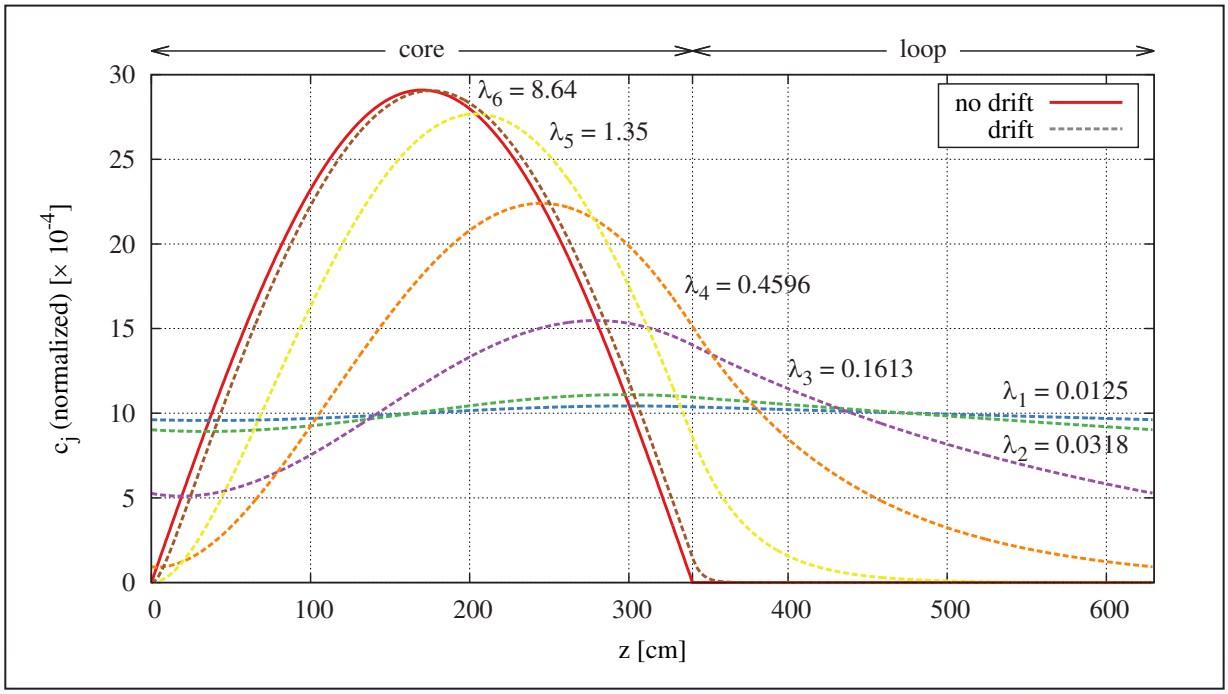



**Figure 29. MSR delayed neutron precursor drift modeling**

Several ATF and advanced cladding concepts are being considered by industry. Some of these concepts are planned for lead test rods in the next one to two years. The SCALE team is assessing SCALE neutronics capabilities for ATF designs, including the identification of relevant benchmark experiments for validation, and code enhancements to improve SCALE's modeling accuracy. The focus is on lattice level investigations for ATF concepts, such as Cr-doped $UO_2$, greater-than-5% enriched $UO_2$, advanced cladding types, and uranium-silicide fuel. Once the assessment is completed, Polaris will be updated for the accurate modeling of ATF fuel concepts. Potential enhancements may include modifications to the energy group structure in the MG library, updates to the nuclear data library such as modified self-shielding factors or scattering data, and updates to the Polaris input interfaces for simple definition of ATF compositions or geometries.

Another capability under development will enable lattice physics calculations with Shift through the established Polaris input and output definitions. This capability will provide reference solutions for non-LWR fuel designs; nodal cross section data will be generated via Shift's CE Monte Carlo solution using the same inputs as the Polaris MG approach. Polaris, which is designed for MG calculations, uses the Embedded Self-Shielding Methodology (ESSM) to generate problem-dependent cross sections and a method of characteristics (MOC) transport solver to generate flux solutions that are subsequently used to produce nodal core simulator data for PARCS. The Shift Monte Carlo interface will allow definition of the Monte Carlo sampling parameters and tallies needed for nodal cross section generation. The construction of the lattice geometry will be updated to create Shift native geometry.

### *Shift Integration for Depletion and Nodal Data Generation*

Shift is being integrated into the TRITON sequence to provide high-fidelity CE Monte Carlo depletion capabilities. CE depletion is currently available in the SCALE 6.2 TRITON depletion sequence through use of the KENO Monte Carlo code for neutron transport calculations. However, the KENO reference solution requires significant computational resources that were not designed for large parallel calculations and are inadequate for full core reactor analysis. To support simulation of advanced reactor concepts requiring increasingly complex geometry, a highly parallelizable reference solution is needed. This solution will be provided by Shift.

Additional features are being added to generate few-group nodal cross sections using Shift. Currently, nodal data can only be generated for 2D geometries in SCALE using NEWT or Polaris. Advanced reactors differ significantly from LWRs in geometry and neutron spectra, necessitating different solution methods. The current MG methods are highly optimized for LWRs. Rather than generate a new group structure and cross section processing method for each advanced reactor class, a CE Monte Carlo nodal data generation solution using Shift will be applicable for any solid-fuel reactor design and scalable to high-performance computing platforms. Particle-based fuel designs such as TRISO require significant complexities for the user to model. The geometric placement of individual fuel grains and/or fuel pebbles will be automated so the user may simply specify the number of particles in a fuel volume or the number of pebbles in a core.

### *Shift Integration for Criticality and Shielding Analysis*

As part of the SCALE modernization effort, Shift is also being implemented into SCALE to replace KENO for criticality safety (CSAS) and sensitivity/uncertainty (TSUNAMI) calculations. A new MAVRIC radiation shielding sequence using Shift is under development. It will use Shift instead of Monaco for hybrid deterministic / Monte Carlo radiation shielding applications. For SCALE 6.3, the existing KENO- and Monaco-based sequences, as well as the updated Shift sequences, will be available to facilitate transition to the enhanced capabilities.

### *Multigroup Nuclear Data for Advanced Concepts*

For nuclear data needed to support advanced reactors and ATF, a generic very fine (VF) 1000+ group library is being developed that is applicable to a wide range of reactor spectra, including thermal and fast systems. This VF library will be available to generate collapsed application-specific libraries. Recommended collapsed group structures may be provided for different reactor concepts, but only the generic VF library will be maintained and distributed with SCALE. An automated capability for users to collapse reactor-specific libraries from the generic VF library is also planned for development in 2019, following SCALE 6.3.

### *Improved SCALE Integration for Fuels Performance and Severe Accident Analysis*

The SCALE connectivity to other NRC licensing tools is also being enhanced by improving the interface for SCALE source terms to MELCOR and the MELCOR Accident Consequence Code System (MACCS) for severe accident analysis. Capabilities are also being included for SCALE to provide power distributions and burnup information for the new FAST fuels performance code, which is integrating and extending the capabilities of FRAPCON and FRAPTRAN for current and advanced concepts.

## Enhancements in the Fulcrum User Interface

Users of Fulcrum often request the ability to visualize geometry in 3D. In a significant enhancement for SCALE 6.3, advanced 3D capabilities will be available. As demonstrated in Figure 30, the new capabilities allow for custom model cutting, transparency layers, and many other desirable features.

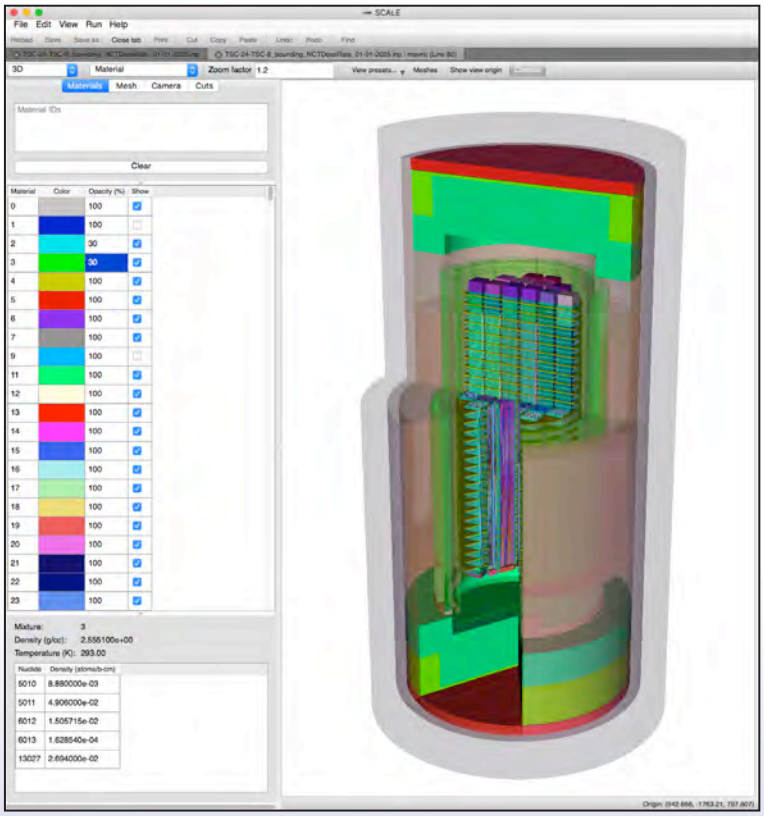



**Figure 30. SCALE 6.3 Fulcrum user interface**
3D visualization of a spent fuel canister

## Sponsored Activities

The maintenance and development of SCALE and AMPX are supported by several sustaining sponsors who have provided support over many years, as well collaborating sponsors who interact with the SCALE team for particular enhancements important to their missions or integration with their tools. Since 1976, the NRC has been the historical lead sponsor in the development of SCALE, with support provided by both the Office of Nuclear Material Safety and Safeguards (NMSS) and the Office of Nuclear Regulatory Research (RES). Since 1987, SCALE maintenance and development activities have been cosponsored by DOE and the National Nuclear Security Administration (NNSA). Details on sponsors are in Table 4 provided below.

### Table 4. Sponsor information

| | Sponsor | Description |
|---|---|---|
| Sustaining Sponsors | NRC/NMSS/Division of Spent Fuel Management (DSFM) | Criticality, shielding, source terms, and validation methods for spent nuclear fuel licensing |
| | NRC/RES/Division of Systems Analysis (DSA)/ Fuel and Source Term Code Development Branch (FSCB) | Nuclear data, lattice physics, criticality safety, depletion, shielding, source terms, and validation for current and advanced reactor licensing |
| | NNSA/NCSP | Criticality safety analysis, validation methods, criticality accident alarm system analysis, and nuclear data processing |
| | DOE/Packaging Certification Program (PCP) | Shielding and source terms for radioactive material packaging |
| Collaborating Sponsors | DOE/Office of Nuclear Energy (NE)/ Nuclear Energy Advanced Modeling and Simulation (NEAMS) | Depletion and decay methods, nuclear data uncertainty analysis, and integration with other NEAMS tools |
| | DOE/NE/Consortium for Advanced Simulation of Light Water Reactors (CASL) | Cross section data and methods integrated with CASL tools |
| | DOE/Technology Commercialization Fund (TCF) | Enhancements for molten salt reactors (MSRs) |
| | NNSA/Office of Defense Nuclear Nonproliferation (NA-22) | Enhancements for nonproliferation analysis |
| | Chinese Academy of Sciences (CAS)/Shanghai Institute of Applied Physics (SINAP) | Enhancements for fluoride salt-cooled high-temperature reactors (FHRs) |
| | ORNL/Laboratory Directed Research and Development (LDRD) | Sensitivity/uncertainty methods for isotope production |

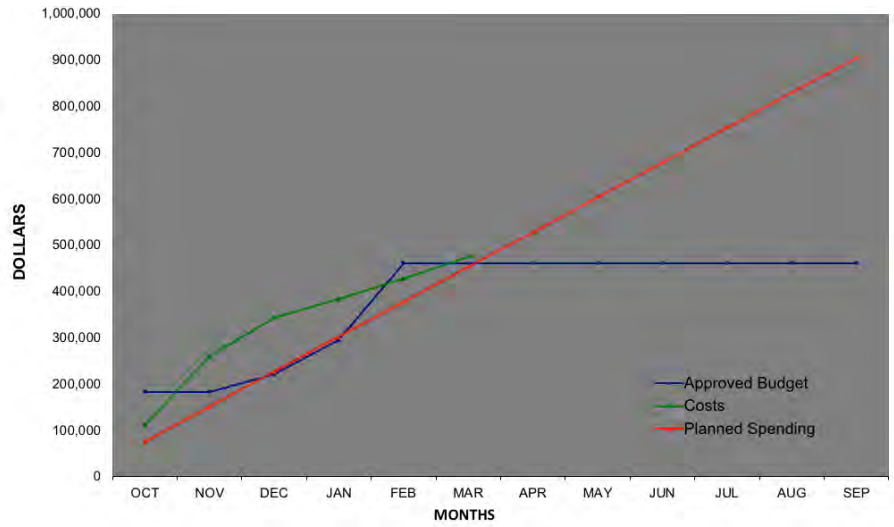

http://scale.ornl.gov

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtasks: Information Preservation & Dissemination, ICSBEP (IP&D1), Website and Red Net (IP&D2)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $0
2. Approved FY-2018 Budget = $984,000 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter in FY-2018) = $474,568
4. Projected carryover into FY-2019 = $79,000 (8%)

## ACCOMPLISHMENTS

ICSBEP Accomplishments (IP&D1)

- OECD NEA plans to host the 2018 ICSBEP Meeting on October 22-26, 2018 at NEA Headquarters, 46 Quai Alphonse Le Gallo, 92100 Boulogne-Billancourt, Paris, France. NCSP evaluations in progress for this meeting include:
  - IER422 [SCRaP] evaluated by T. Cutler and Jennifer Arthur (LANL)
  - IER206 [BUCCX] evaluated by G. Harms (SNL)
  - IER451 [BUCCX-Ti] evaluated by G. Harms (SNL)
  - IER407 [ISSA] evaluated by A. Nelson et al. (LLNL)
- Additionally, LANL plans to complete IER151 [NCT#2] in FY2018Q4 in ICSBEP format but with restricted distribution.
- Participated as CEdT reviewer for the following SNL evaluations scheduled for ICSBEP publication in 2019, or beyond:
  - IER451 [BUCCX w/Ti/Al sleeves] CED-3b Report by David Ames (SNL)
  - IER305 [BUCCX/7uPCX w/Mo] CED-1 Report by Nicolas Leclaire (IRSN)
- Reviewed *The 2018 Edition of the ICSBEP Handbook* for publication in the Transactions of the American Nuclear Society.

Website Accomplishments (IP&D2)

- Provided a 'live' demonstration of the modernized NCSP website at the NCSP Technical Program Review at ORNL
- Providing website updates as requested by NCSP Management.
- Archived and retained the legacy NCSP website at https://cedt.llnl.gov, which includes the IER/CEdT database that will be maintained until transfer to NNSA G2. This site can also be accessed by redirect from https://ncsp-beta.llnl.gov. There is currently no firm date for transfer to G2.

Red Net Accomplishments (IP&D2)

- Updated NTS-LAN/NCERC classified network images and servers and performed required monthly "authenticated" scans
- Supporting iSRD expansion to B600, U1a and NSF
- Rebuilt 3 unclassified computer systems in support of NCERC personnel.
- Provided equipment inspections, certifications and data transfers in support of:
  - IER-299: KRUSTY
  - IER-462: NCSP hands-on training courses (LANL)
  - IER-464: NCSP hands-on training courses (LLNL)
  - IER-466: NCERC Operational Support (LANL IE1)
  - IER-490: NA-80 Science Measurements Nov 2017

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtasks: Information Preservation & Dissemination, ICSBEP (IP&D1), Website and Red Net (IP&D2)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018

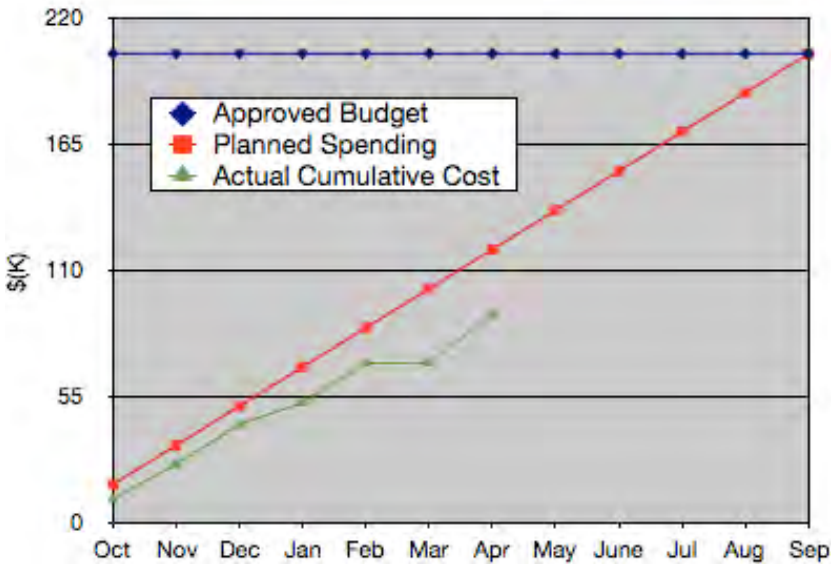

| MILESTONES FY2018 | | ISSUES/PATH FORWARD |
|---|---|---|
| Manage all aspects of the DOE NCSP participation in the ICSBEP as required to ensure the finalizing and publishing ICSBEP evaluations per IE schedule (IPD1: All Qtrs). | | • Approved budget reflects actual funds received on October 13, 2017, December 22, 2017, January 12, 2018, February 8, 2018, and February 27, 2018.<br>• Planned spending is from the 5YP, Table 2.2-3.<br>• LANL ICSBEP evaluations deferred to 2019, or beyond, include:<br>- Goda to correct errors in HMF086 (Godiva-IV TA-18) in 2019<br>- Hutchinson to complete IER121 [Np Subcritical] in 2019<br>- JSI to complete IER192 [Class Foils Moderated/Reflected by Lucite] in 2019<br>- Sanchez to evaluate IER299 [KRUSTY] in 2019<br>- Evaluation of new Godiva-IV experiments in DAF on hold<br>- IER423 [Flattop] evaluation on hold<br>• SNL to defer completion of ICSBEP evaluations for IER209 [7uPCXvH] and IER230 [7uPCXvP] to 2019.<br>• LLNL working with Profile Unity vendor and LANL to resolve Kerberos login issues on NTS-LANL (NCERC).<br>• No date for transfer of IER/$C_E$dT database to NNSA G2. |
| Provide status reports on LLNL participation in US and International IP&D collaborations (including ICSBEP) and provide brief trip summary report to NCSP Manager on items of NCSP interest (IPD1: All Qtrs). | | |
| Maintain, operate and modernize the NCSP website, databases, and provide user assistance as required (IPD2: All Qtrs). | | |

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

| NCSP Element and Subtask: Nuclear Data BNL Task 1<br>M&O Contractor Name: BNL<br>Point of Contact Name: David Brown<br>Point of Contact Phone: 631-344-2814 | Reference: B&R DP 0902090<br>Date of Report: May 10, 2018<br>Page 1 of 1 |
|---|---|

## BUDGET




1. Carryover into FY-2018 = $15,478
2. Approved FY-2018 Budget = $204,912 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter in FY-2018 = $91,267

## ACCOMPLISHMENTS

- ENDF/B-VIII.0 released 2 Feb 2018
- Happy 50th CSEWG!
- ENDF/B-VIII.0 release page now up on NNDC website (http://www.nndc.bnl.gov/endf/b8.0/)
  - This means errata page is also now up (http://www.nndc.bnl.gov/endf/b8.0/errata.html) *sigh*
  - GNDS and POINT2018 processed files are available

## MILESTONES

| | |
|---|---|
| Maintain and upgrade ADVANCE code system by performing data verification of new NCSP evaluations and performing quality assurance on the data as required and provide status reports on all nuclear data support activities to the NCSP Manager (Q1, Q2, Q3, Q4) | |
| If mandated by CSEWG, release new ENDF library (Q3) | |

## ISSUES/PATH FORWARD

- Awaiting server hardware upgrades before beginning to improve ADVANCE
- CSEWG recommends improvements to ENDF/B evaluation review process
- Waiting for official LANL ACE files for ENDF/B-VIII.0

- Graphite changes in β6 & β7 necessitate a report/article describing changes and their testing.

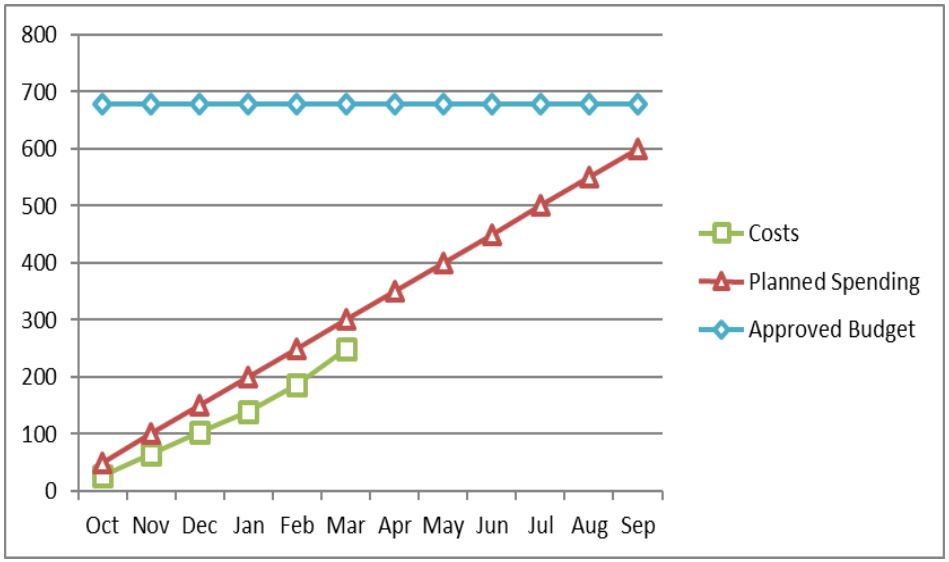
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

NCSP Element and Subtask: ND1 (Nuclear Data Evaluation and Testing)
M&O Contractor Name: LANL
Point of Contact Name: Bob Margevicius / Bob Little
Point of Contact Phone: 505-665-8965 / 505-665-3487

Reference: B&R DP0902090
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $0.
2. Approved FY-2018 Budget = $678,000 (Includes carryover from FY-2017).
3. Actual Spending through the end of this quarter in FY-2018 = $249,838.
4. Projected carryover into FY 2019 = $78,000.

## ACCOMPLISHMENTS

- P(nu) for n+Pu239 as a function of incident neutron energy was released as part of the ENDF/B-VIII.0 library. The thermal distribution follows experimental data, and CGMF calculations were used at higher energies to estimate energy-dependent parameters of the Terrell distribution.
- We are working with the ChiNu team to interpret the measured angular distributions of the prompt fission neutrons using our CGMF code. This distribution depends on the anisotropy of the fission fragments as a function of incident neutron energy, on the neutron-fragment angular distribution, and on the distributions of pre-scission neutrons.
- In order to enable more realistic MCNP simulations of the 6Li detectors used in the ChiNu experiments, we have incorporated an improved representation of the neutron, deuteron, and alpha-particle spectra for the n+6Li breakup reaction into the ENDF evaluation. The produced file was given to the ChiNu team.
- The evaluation of prompt fission gammas is ongoing, and some of the results were included in ENDF/B-VIII.0. This work will be finalized by including the multiplicity-dependent spectra.
- The U236(n,g) reaction was re-evaluated using the CoH3 code with the updated M1 scissors mode photo-strength function. Results agree very well agree with the new DANCE data. Three Phys. Rev. C papers were published on this subject. A new evaluation of U236 is planned.
- New modeling of prompt fission neutrons and gammas based on the deterministic statistical decay of fission fragments is in a

| | |
|---|---|
| | data production stage. A paper on this subject was accepted for publication in J. Nuclear Science and Technology in April.<br><br>• We presented a talk on "LANL Nuclear Data for NCSP" at the TPR in March.<br><br>• Los Alamos NCSP / ND staff co-authored eight of the articles in the Nuclear Data Sheets special issue on Nuclear Reaction Data focused on the release of ENDF/B-VIII.0, which appeared in February 2018 (https://www.sciencedirect.com/journal/nuclear-data-sheets/vol/148/suppl/C) |

| MILESTONES | | ISSUES/PATH FORWARD |
|---|---|---|
| Provide status reports on LANL participation in US and International Nuclear Data collaborations (ND1; All Qtrs) | | The new Pb-208 evaluation has not been finalized yet. We expect that this should be complete before the end of the FY |
| Conduct CSEWG Data Evaluation Committee session (ND1: Q1) | | |
| Report data testing results with ENDF/B-VIII.0 cross sections (ND1: Q1) | | |
| Report planning status of LANL initiative focused on machine learning for nuclear data (ND2: Q4) | | |
| Deliver nuclear data evaluations as indicated in Appendix B of the 5-year plan (ND1: Q4) | | |

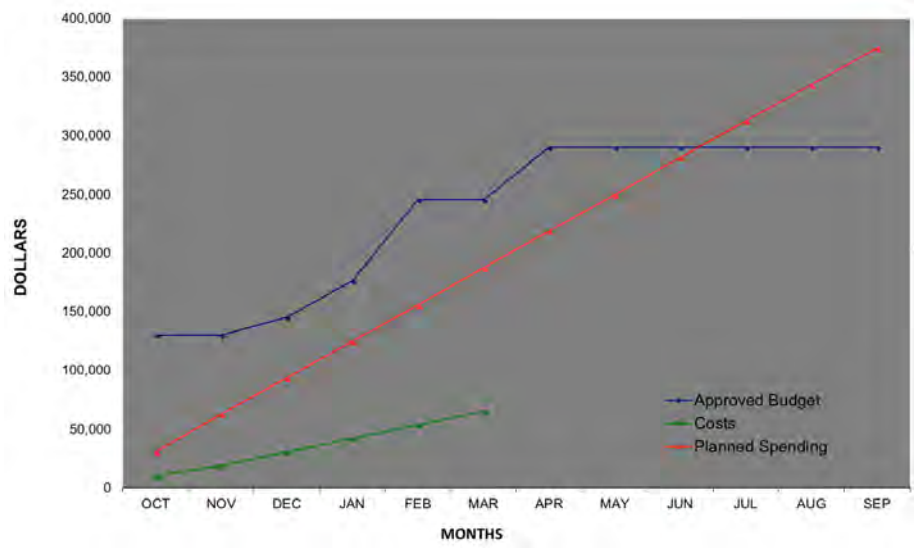
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtask: Nuclear Data
DFGs (ND1), TSLs (ND2), Codes (ND3), Doppler (ND5), Cadmium (ND6)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $55,705
2. Approved FY-2018 Budget = $463,705 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter (in FY-2018) = $65,238
4. Projected carryover into FY-2019 = $88,705 (19%)

## ACCOMPLISHMENTS

Delayed Fission Gammas (ND1)

- LLNL continuing to assist ORNL in comparing DFG multiplicity and spectra calculated by COG and ORIGEN.

Thermal Scattering Laws (ND2)

- NCSU continued work on molecular dynamics (MD) models for light water. The TIP4P/2005f force field was successfully parametrized and implemented within the LAMMPS code to perform the simulations. As indicated previously, the simulations reproduced key properties of water including density and diffusivity (of the water molecule) at 298 °K and 1 atm. Moreover, with the current parametrization, the simulations were able to reproduce the excitation density of states (DOS) used in the ENDF/B-VIII.0 analysis. Currently, the MD parameters that are used to produce the temperature dependent DOS are not published. Therefore, using the NCSU MD models, work can proceed to improve the parametrization and TSL generation.

Next Generation Codes (ND3)

NCSU continued work on the *FLASSH* code to improve execution capabilities. A new checker engine was implemented to check input syntax. The new checker now supports any non-number separated list. Anything except "+, -, /, E, e" can be used to separate a list of input numbers. For example, both "2.1, 2.2, 2.3" and "2.1TAB2.2TAB2.3" are now supported format of number lists. The syntax checker now checks whether the number of elements in the list matches the indicated total number. For example, the syntax checker will check if the number of β points being input matches the description. In addition, better handling of "Error" return has been implemented. When error is detected by the GUI, it marks the wrong input with red background and gives specific reasons for each wrong input. In addition, the GUI will remember the correct input when opening an existing file. If a wrong input is later made, it will revert to the previous correct one by clicking "cancel".

Advanced Doppler Broadening (ND5)

- NCSU continued work with the SAMMY code to perform Doppler analysis using both the free gas model (FGM) and the crystal lattice model (CLM). Calculations were performed to investigate the Doppler broadening operation for the absorption cross section of U (in a $UO_2$ lattice) at the first resonance of 6.67 eV

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

NCSP Element and Subtask: Nuclear Data
DFGs (ND1), TSLs (ND2), Codes (ND3), Doppler (ND5), Cadmium (ND6)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018


and at a temperature of 70 °K. In addition, the analysis compared the impact of using the ENDF/B-VII.1 phonon density of states and the ENDF/B-VIII.0 phonon density of states (recently produced at NCSU). In this case, differences of nearly ±5% in the broadened cross section may be attributed to the phonon density of states. The FGM model results are currently being analyzed to ensure consistency. In addition, experimental data (at various temperatures) is being collected and investigated to compare to the calculations.

Radiative Capture Gamma Production in Cadmium (ND6)

- Submitted the proposal, *Measurement of Radiative Capture Gamma Production in Cadmium*, for NCSP funding consideration in FY-2019 on February 8, 2018. A similar proposal, *Cadmium Neutron Capture Gamma Ray Spectra and Nuclear Structure*, was submitted to the DOE Office of Science.

| MILESTONES FY2018 | |
|---|---|
| Provide status on LLNL ND activities in NCSP Quarterly Progress Reports (ND1, ND2, ND3, ND5, ND6: All Qtrs) | |
| Provide status on LLNL/NCSU nuclear data activities to NCSP Manager (ND2, ND3, ND5: All Qtrs) | |
| Provide status on LLNL/IRSN nuclear data activities to NCSP Manager (ND1: All Qtrs) | |
| Deliver thermal neutron scattering data evaluations as indicated in Appendix B of the 5-Year Plan (ND2: Q4) | |

## ISSUES/PATH FORWARD

- Approved budget reflects actual funds received on October 23, 2017, December 22, 2017, January 12, 2018; February 8, 2018; and February 27, 2018.
- Planned spending reflects the 5YP, Table 2.4-7.
- Actual spending has yet to include $45,459.40 (overage) on the previous contract, which is in process of transferring to the current contract.
- The thermal scattering data evaluations listed in Accomplishments were completed well in advance of the Appendix B schedule.

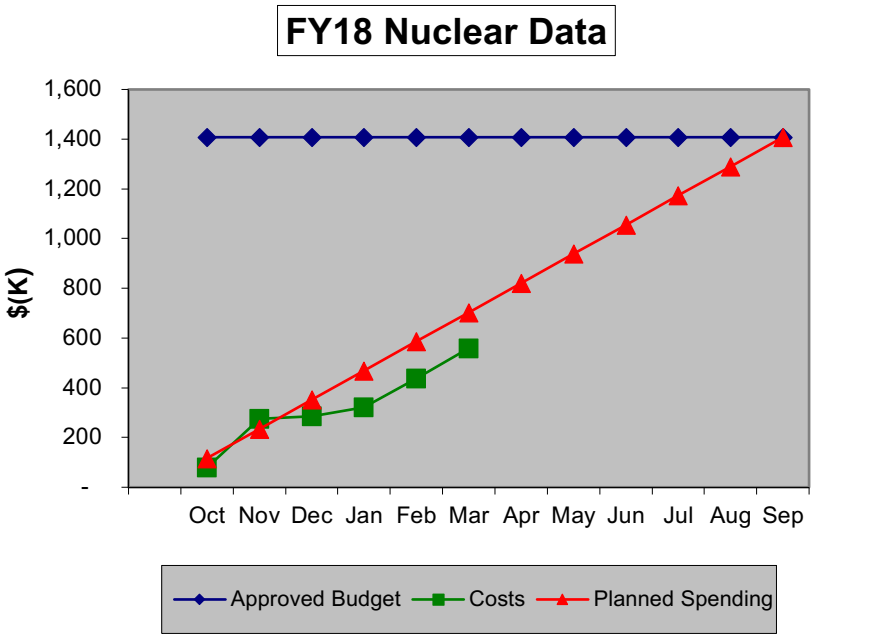
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

**NCSP Element and Subtask:** ORNL – ND1, 6, 7, 8
**M&O Contractor Name:** ORNL
**Point of Contact Name:** Doug Bowen
**Point of Contact Phone:** (865) 576-0315

**Reference:** DP0902000/ORNL
**Date of Report:** May 01, 2018

## BUDGET




1. **Carryover into FY 2018** = $41K
2. **Approved FY 2018 Budget** = $1,408K (includes carryover)
3. **Actual spending for 1st Quarter FY 2018** = $287K
4. **Actual spending for 2nd Quarter FY 2018** = $273K
5. **Actual spending for 3rd Quarter FY 2018** = $0
6. **Actual spending for 4rd Quarter FY 2018** = $0

## ACCOMPLISHMENTS

**ND6 – SAMMY Modernization**

- **Status report on all SAMMY modernization progress**
  - A recently developed modern C++ library of Coulomb functions over the largest known domain of complex input parameters [1] has been integrated into the SAMMY code to replace the legacy Fortran implementation used by the SAMMY code. This enables computation of R-matrix shift functions for sub-threshold reactions allowing for evaluated endothermic channels at energies below their thresholds.
  - Coulomb functions are now available for easy linking and distribution by any other SCALE code, besides SAMMY and AMPX where it has been recently employed. This increases the simplicity and clarity of the SAMMY source code.
  - Code sharing between SAMMY and AMPX will enable rapid adoption of new evaluation techniques and new ENDF formats into AMPX processed libraries.
  - The adoption of the modern Coulomb library into the SAMMY code was implemented in the following 4 steps:
  - Create a C++ Coulomb Functions Application Programming Interface (API) that abstracts the features needed to compute the R-matrix shift and penetrability functions.
    - Extract the legacy SAMMY code that currently provides those features out of SAMMY, and use it to implement the the C++ API above
    - This requires two steps of indirection: one between the Fortran SAMMY and the C++ API, and another between the C++ API and the extracted legacy implementation.
  - SAMMY test cases were run to ensure identical results were obtained, as expected.
  - Implement the C++ API created in step 1. via the modern Coulomb function implementation.

Switch from the extracted legacy Fortran implementation of the C++ API in step 2. to the modern Coulomb function implementation in Step 3 and re-run the test cases.


Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

| **NCSP Element and Subtask:** ORNL – ND1, 6, 7, 8<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference:** DP0902000/ORNL<br>**Date of Report:** May ##, 2018 |
|---|---|
| | **ACCOMPLISHMENTS** |
| | **ND6 – SAMMY Modernization (continued)**<br>○ The same approach will be used for modernization of other SAMMY features, wherever it may be appropriate.<br>○ Analytical expressions for derivatives of the R-matrix shift function, penetrability, and the phase shift for charged particles have been implemented. This constitutes an improvement over a numerical implementation of those derivatives for charged particles in the SAMMY code, and it complements the analytical derivatives already in place inside the SAMMY code for neutral particles.<br>○ The modern Coulomb implementation yields more accurate results than the legacy Fortran implementation. Consequently, several of the composite test cases have been re-baselined using the modern Coulomb function.<br>○ A new test case has been created to test modern Coulomb function library directly<br>○ With the modern Coulomb function library, and with the changes described above, the SAMMY code has successfully passed all its nearly 190 composite test cases, including the new ones described above, and on the following OS/compiler combinations: Mac/gcc, Linux/gcc and Windows/ifort.<br>▪ [1] N. Michel, "Precise Coulomb wave functions for a wide range of complex ℓ, η and z", Computer Physics Communications, Volume 176, Issue 3, 1 February 2007, Pages 232-249, http://doi.org/10.1016/j.cpc.2006.10.004.<br>▪ [2] https://en.wikipedia.org/wiki/Curiously_recurring_template_pattern<br>• **SAMMY modernization progress report (Q4)**<br>○ Work not yet started.<br><br>**ND7 – Collaboration task with GA Tech**<br>○ Contract was set up with GA Tech to initiate work for 2018-2018 school year. This university task will fund an MS student. |

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

| | |
|---|---|
| **NCSP Element and Subtask:** ORNL – ND1, 6, 7, 8<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference:** DP0902000/ORNL<br>**Date of Report:** May ##, 2018 |
| | **ACCOMPLISHMENTS** |
| | **ND8 – Nuclear Data Work Plan for U-233 for the NCSP (Due Q3)**<br>• **Status report**<br>  ○ Drafted report on U-233 evaluated and experimental data situation. Draft report was discussed at NDAG meeting and NDAG agreed to the finding in the report. A re-evaluation with a renormalized fission cross section has to be performed. With the new evaluation benchmark calculations have to be completed to determine the impact. Ultimately it has to be determined if new capture experiments for U233 are required.<br><br>**Y12 ND1 – GELINA depleted Uranium target cost estimate and construction**<br>• **Status report**<br>  ○ Meeting with Y12 engineer to discuss details of the GELINA neutron production target. Provided answers to detailed questions and promised to look and obtain more detailed drawings from JRC-Geel. Y12 is the only place to produce such a target. |

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

| **NCSP Element and Subtask:** ORNL – ND1, 6, 7, 8<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | | **Reference:** DP0902000/ORNL<br>**Date of Report:** May ##, 2018 |
|---|---|---|
| **MILESTONES** | **Status** | **ISSUES/PATH FORWARD** |
| 1. Provide status reports on all nuclear data support activities in NCSP Quarterly Progress Reports (ND1, ND6, ND7: All Qtrs). | | |
| 2. Provide status reports on ORNL participation in US and International Nuclear Data collaborations, and for foreign travel, provide brief trip summary report to NCSP Manager on items of NCSP interest (ND1: All Qtrs). | | |
| 3. Complete cross-section measurement and evaluation deliverables per the nuclear data schedule in Appendix B (ND1: All Qtrs). | | Enriched Zr and Ce-142 experiments delayed due to problems obtaining samples for lease. Ce-142 lease is in progress.<br>The completion of the resonance region evaluation of the isotopes of Cerium is dependent of the availability of the experimental data for isotopically-enriched Ce-142. |
| 4. Complete nuclear data work plan for $^{233}U$ and provide plan to NCSP Manager (ND8: Q3) | | |
| 5. Document SAMMY modernization progress and report status annually to the NCSP Manager (ND6:Q4) | | |

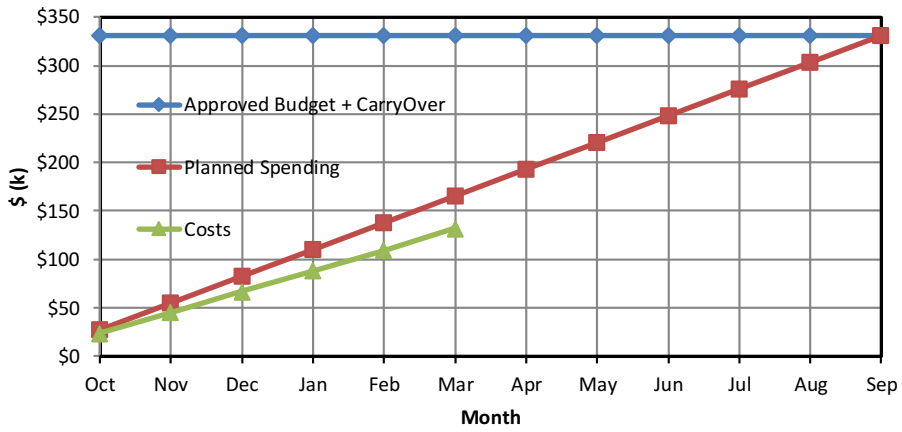

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

**NCSP Element and Subtask**: RPI-ND1- Resonance Region Nuclear Data Measurement Capability at RPI - Perform cross-section measurements and qualification of the new capabilities
**M&O Contractor Name**: RPI
**Point of Contact Name**: Yaron Danon
***Point of Contact Phone***: 518-276-4008

Reference: RPI ND-1
Date of Report: May 2, 2018


## BUDGET




1. Carryover into FY-18: $-8,520
2. Approved FY-18 budget: $340,000, $331,480 (with carryover),
3. Actual spending through the end of this quarter in FY-18: $132,125
4. Projected carryover into FY-19: $10,000

## ACCOMPLISHMENTS

**Q2 accomplishments**:

- Collected self-shielded transmission data with a thick Ta sample
- Completed data reduction for thick Ta sample transmission
- Fitted new resonance parameters for Ta in the RRR of 0.155-2.5 keV

## MILESTONES

| | |
|---|---|
| 1. Complete analysis of measurements from FY-17 (Ta samples) (Q1). | |
| 2. Complete transmission measurement per the nuclear data schedule in Appendix B (Q3) ( additional Ta data as needed) | |
| 3. Complete capture measurement per the nuclear data schedule in Appendix B (Q3) (additional Ta data as needed) | |
| 4. Complete data analysis for transmission and capture measurements and provide the data to ORNL as needed to support the evaluation effort per the nuclear data schedule in Appendix B.(Q4) | |
| 5. Provide status reports on all nuclear data support activities in NCSP Quarterly Progress Reports (All Q). | |
| 6. Provide status reports on RPI participation in US and International Nuclear Data collaborations and for foreign travel, provide a brief trip summary report to NCSP Manager on items of NCSP interest (All Q). | |

## ISSUES/PATH FORWARD

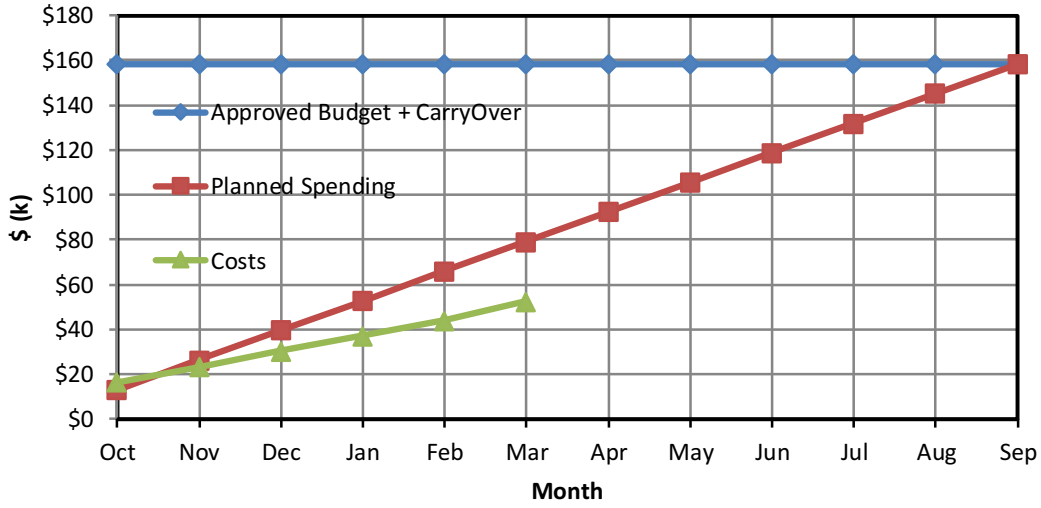
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

**NCSP Element and Subtask**: RPI-ND2- Thermal neutron scattering measurements
**M&O Contractor Name**: RPI
**Point of Contact Name**: Yaron Danon
***Point of Contact Phone***: 518-276-4008

Reference: RPI ND-2
Date of Report: May 2, 2018


## BUDGET




1. Carryover into FY-18: $32,481
2. Approved FY-18 budget: $126,000, $158,481 (with carryover)
3. Actual spending through the end of this quarter in FY-18: $52,568
4. Projected carryover into FY-19: $15,000

## ACCOMPLISHMENTS

**Q2 Accomplishments**

- Polyethylene manuscript is under review by Annals of Nuclear Energy
- Completed Ice-1h evaluation that is ready for testing.
- Presented results on Polyethylene, Lucite and Quartz in NCSP technical review at ORNL.

## MILESTONES

| | |
|---|---|
| 1. Complete thermal scattering measurements per the nuclear data schedule in Appendix B ( Q3) (these are repeat measurment if needed) | |
| 2. Complete thermal scattering data analysis and provide data to ORNL as needed to support the evaluation effort per the nuclear data schedule in Appendix B (Q4). | |
| 3. Provide status reports on all nuclear data support activities in NCSP Quarterly Progress Reports (All Q). | |
| 4. Provide status reports on RPI participation in US and International Nuclear Data collaborations, and for foreign travel, provide a brief trip summary report to NCSP Manager on items of NCSP interest (All Q) | |

## ISSUES/PATH FORWARD

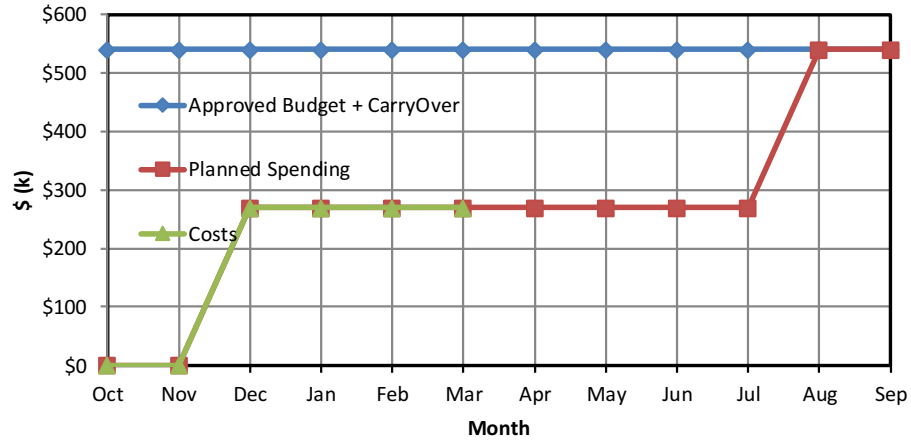
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

**NCSP Element and Subtask**: RPI-ND3- LINAC 2020 plan, Nuclear Data Capabilities Maintenance plan
**M&O Contractor Name**: RPI
**Point of Contact Name**: Yaron Danon
***Point of Contact Phone***: 518-276-4008

Reference: RPI ND-3
Date of Report: May 2, 2018


## BUDGET




1. Carryover into FY-18: $0
2. Approved FY-18 budget: $960,000
3. Actual spending through the end of this quarter in FY-18: $960,000
4. Projected carryover into FY-19: $0

## ACCOMPLISHMENTS

**Accomplishments in Q2**

- Accelerator Structure Fabrication Design Review Meeting took place on April 2018. Accelerator structure fabrication first section to begin sometime in June 2018.
- New LINAC Control System Specifications developed has begun (Michael Bretti [RPI] in conjunction with Valery Dolgashev [SLAC]).
- Factory acceptance test of first modulator is scheduled for the week of June 2018 with an RPI representative.
- Modulator building construction planned be completed by the end of July.

## MILESTONES

| | |
|---|---|
| 1. Place accelerator sections contract with vendor (Q1) | |
| 2. Complete 1st modulator factory test in coordination with NR (Q2) | |
| 3. Complete modulator(s) factory test in coordination with NR. (Q4) | |
| 4. Complete accelerator section(s) factory test in coordination with NR. (Q4) | |
| 5. Provide status reports on all nuclear data support activities in NCSP Quarterly Progress Reports (Q1, Q2, Q3,Q4) | |

## ISSUES/PATH FORWARD

The missed millstone is expected to be completed in June (Q3).

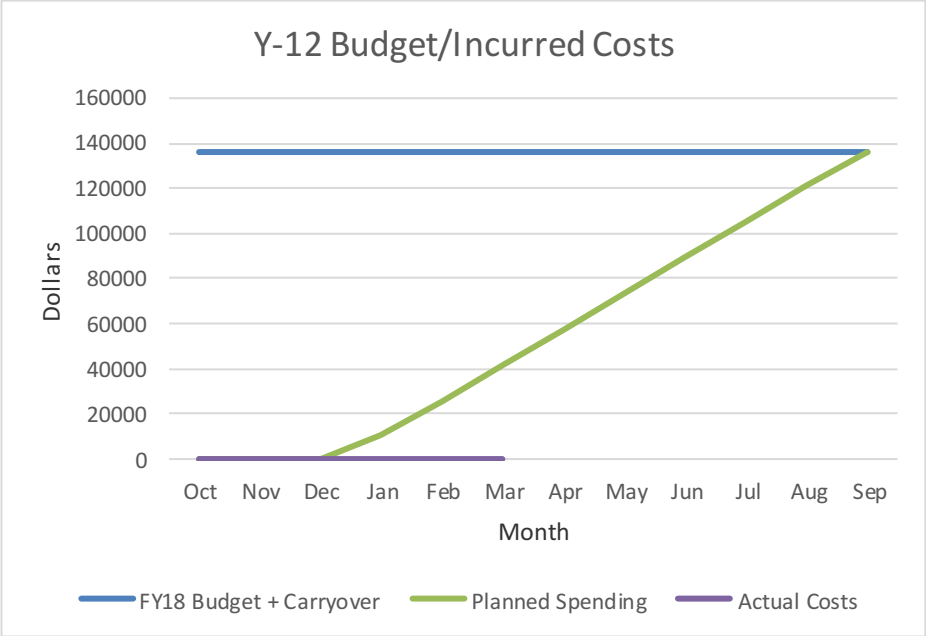
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

NCSP Element and Subtask: Y12- (Prepare Cost Estimate for GELINA Target)
M&O Contractor Name: Y-12
Point of Contact Name: Kevin Kimball
Point of Contact Phone: 865-576-6675

Reference: B&R DP
Date of Report: April 6, 2018


## BUDGET




1. Approved FY-2018 Budget = $136,432; CR To Date = $136,432
2. Actual Spending through the end of this quarter in FY-2018 = $0

## ACCOMPLISHMENTS

- Reviewed existing drawings
- Identified additional detailed component drawings needed for cost estimating
- Requested component drawing set from GELINA (via Klaus Guber, ORNL)

## MILESTONES

| | |
|---|---|
| Obtain existing target drawings (Q1) | |
| Review existing target drawings for completeness and request additional required information (Q2) | |
| Meet with Y-12 production personnel and external suppliers to obtain estimated fabrication costs (Q3) | |
| Complete cost estimate for fabrication of GELINA(Q4) | |

## ISSUES/PATH FORWARD

- Missing detailed component drawings are necessary to provide cost estimate. The specific drawings have been requested of GELINA through Klaus Guber/ORNL.
- The process for estimating fabrication costs will be undertaken once the complete drawing set is obtained.

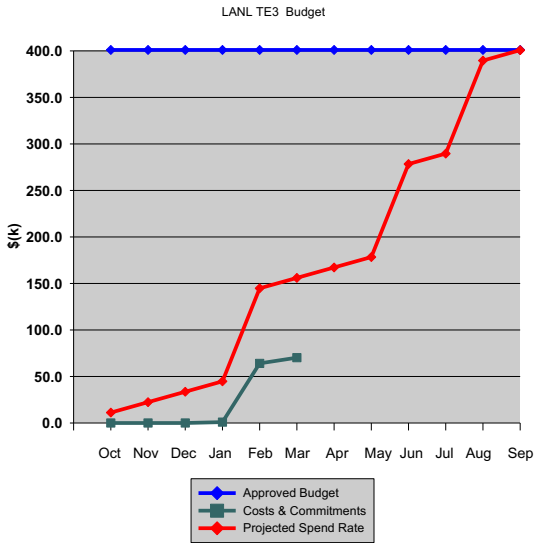
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

**NCSP Element:** Integral Experiments LANL TE 3
**M&O Contractor Name:** Los Alamos National Laboratory (LANL)
**Point of Contact Name:** Robert Margevicius
**Point of Contact Phone:** (505) 665-8965

Reference: B&R DP0902090
Date of Report: May 11, 2018

## BUDGET




1. **Carryover from last FY-17: $38K**
2. **Total available funding this FY-18: $401K**
3. **Total spending through the end of the report quarter Q2: $70.3K**
4. **Carryover into new FY-19: $0.**

## MAJOR ACCOMPLISHMENTS

- Participated in regularly scheduled NCSP T&E conference calls.
  - Supported execution of the second week (NCERC) of the two week training for Criticality Safety Analysts.

## ISSUES/PATH FORWARD

- None

- None

# NCSP Quarterly Progress Report (FY-2018 Q2) cont'd.

| **NCSP Element:** Integral Experiments LANL TE 1<br>**M&O Contractor Name:** Los Alamos National Laboratory (LANL)<br>**Point of Contact Name:** Robert Margevicius<br>**Point of Contact Phone:** (505) 665-8965 | | Reference: B&R DP0902090<br>Date of Report: May 11, 2018<br>x | |
|---|---|---|---|
| **MILESTONES** | | **MILESTONES** | |
| • Provide class room and hands on training at LANL and at NCERC in accordance with the approved schedule and provide status reports on all training activities in the NCSP Quarterly Progress Reports (TE1-T1). (Q1, Q2, Q3, Q4). | M | | |
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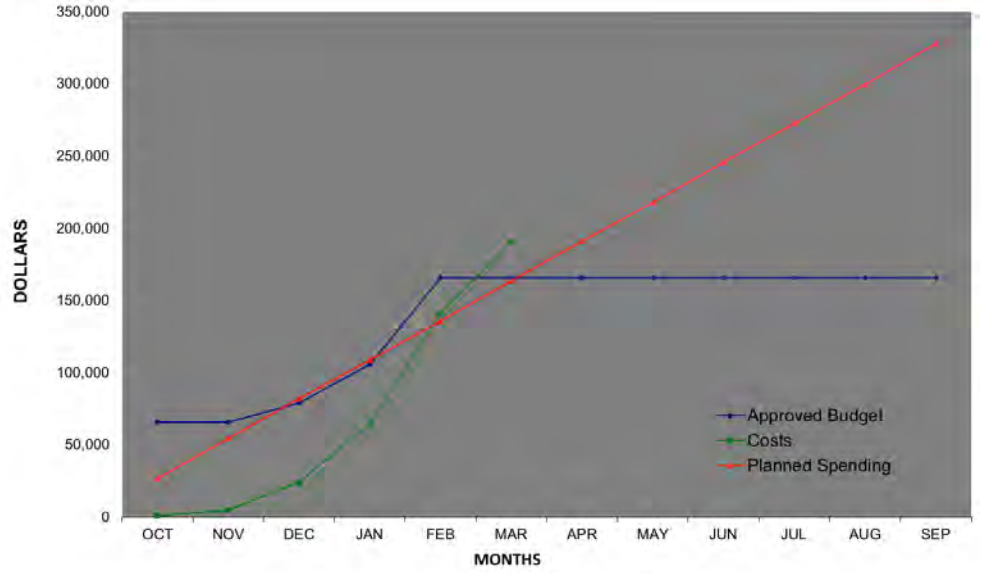
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed before or on Schedule, Purple = Completed Late

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtasks: Training & Education,
"Hands-on" Training (TE1), Classroom Instruction (TE3), TACS with Be (TE8)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2017


## BUDGET




1. Carryover into FY-2018 = $0
2. Approved FY-2018 Budget = $356,000 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter in FY-2018) = $190,568
4. Projected carryover into FY-2018 = $28,000 (8%)

## ACCOMPLISHMENTS

- Provided registration and logistics support for:
  - 2-week CSE course on Jan. 29-Feb. 9, 2018
  - 1-week Managers course on April 15-20, 2018 at SNL
  - 1-week Managers course on June 11-15, 2018 at NFO/NCERC
  - 2-week CSE course on Aug. 13-24, 2018
- Provided academic and hands-on instruction for the 2-week CSE course at NATM/NCERC on January 29-February 9, 2018 including the following modules:
  - NCS Fundamentals
  - NCS Evaluation
  - Evaluation Workshops
  - Introduction to Experimental Methods
  - TACS
  - Emergency Response (new!)
- Completed a Beryllium Hazard Assessment and received approval for use at the DAF from the MSTS Beryllium Subject Matter Expert. Procured packaging materials for storage at NNSS.
- Received and completed characterization and dose-rate measurements for a new, long-life, Am-Be source to replace the short half-life $^{252}$Cf source. A new $^{252}$Cf source has been procured by another LLNL Program and is also available for use with TACS.
- Participated in all T&E teleconferences.

## MILESTONES FY2018

| | |
|---|---|
| Update, maintain and support the registration process and provide classroom and "hands-on" TACS training in accordance with the schedule approved by the NCSP Manager (TE1: All Qtrs). | |
| Provide LLNL support for FY2018 classroom instruction at the NSF or NATM and participate in T&E development activities in accordance with the schedule approved by the NCSP Manager (TE2: All Qtrs). | |
| Evaluate the TACS with Be shells and provide a status report in the FY2018 Q4 quarterly status report to the NCSP Manager (TE8: Q4). | |

## ISSUES/PATH FORWARD

- Approved budget reflects actual funds received on October 13, 2017; December 22, 2017; January 12, 2018; February 8, 2018; and February 27, 2018.
- Planned spending is from the 5YP, Table 2.5-5.

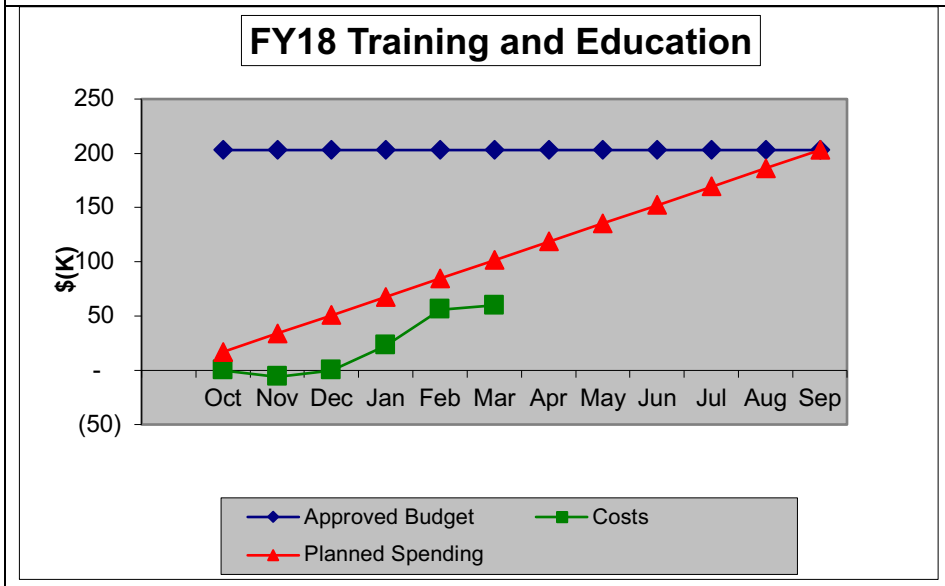
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

**NCSP Element and Subtask:** TE1 and TE5
**M&O Contractor Name:** ORNL
**Point of Contact Name:** Doug Bowen
**Point of Contact Phone:** (865) 576-0315

**Reference:** DP0902000/ORNL
**Date of Report:** May 1, 2018


## BUDGET




1. **Carryover into FY 2017** = $0K
2. **Approved FY 2017 Budget** = $203K (includes carryover)
3. **Actual spending for 1st Quarter FY 2018 = $0K**
4. **Actual spending for 2nd Quarter FY 2018 = $0K**
5. **Actual spending for 3rd Quarter FY 2018 = $0K**
6. **Actual spending for 4th Quarter FY2018 = $0K**
7. **Projected Carryover into FY 2018** = $0K

## ACCOMPLISHMENTS

- **TE1**:
  - Initiated a final report on the CSSG assessment (CSSG tasking 2016-01) to document the resolution of all comments.
  - Coordinated and executed the 2-week hands on course Jan. 29-Feb. 9, 2018 at the National Atomic Testing Museum, Sandia National Laboratory, and the NCERC. Bowen, Chapman, Hicks, and Marshall supported the course as instructors. Lori Scott and Becka Hudson provided administrative support for the course.
  - Initiated course planning and preparatory telecons for the Sandia Manager Course April 16-20, 2018.
- **TE5**:
  - Began to prepare for a 1-day S/U introductory training course at SRNS on April 23, 2018. This is a collaborative task with LANL (Brown, Alwin, Rising). B.J. Marshall, A. Holcomb, and C. Perfetti provided ORNL support.

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

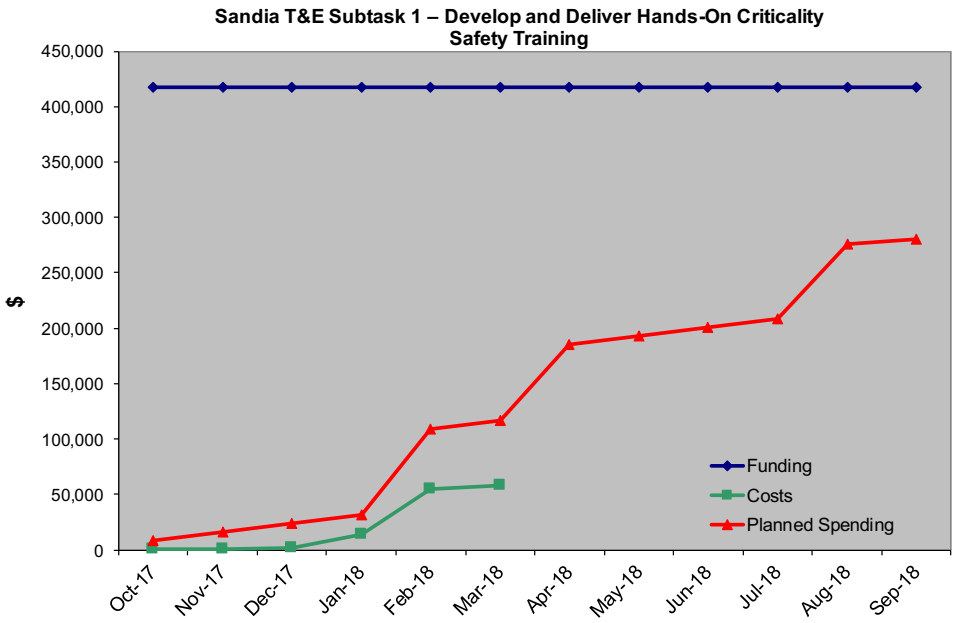
| **NCSP Element and Subtask:** TE1 and TE5<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | | **Reference:** DP0902000/ORNL<br>**Date of Report:** January 26, 2018<br>**Page 2 of 2** |
|---|---|---|
| **MILESTONES** | | **ISSUES/RESOLUTIONS** |
| | **Status** | |
| 1. Provide a status report in NCSP Quarterly Progress Reports on implementation of the NCS training program and resolution of CSSG comments from CSSG tasking 2016-01. (TE1) | | Spending light in Q1. Spending in Q2 and beyond will increase in preparation for the 2-week hands-on course in February 2018. |
| 2. Provide status reports in NCSP Quarterly Progress Reports on improvements/modifications to baseline NCS course training materials based on CSSG assessment report 2016-01, self-evaluation, and feedback from reviewers, observers, trainers, and the NCSP manager. (TE1) | | |
| 3. Provide a status report in NCSP Quarterly Progress Reports on the progress of 1-day onsite introductory validation training conducted at one or more DOE sites. (TE5) | | |

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

| NCSP Element: Sandia T&E Task 1 – Conduct Criticality Safety Training Classes<br>M&O Contractor Name: Sandia National Laboratories (SNL)<br>Point of Contact Name: Gary A. Harms<br>Point of Contact Phone: (505)845-3244 | Reference: B&R DP 0909010<br>Date of Report: March 31, 2018<br>Page 1 of 1 |
|---|---|

## BUDGET




1. Carryover from the Previous FY = $309,801
2. Total Funding Available This FY: $107,968 (new) + $309,801 (carryover) = $417,769
3. Approved Current FY Budget = $280,000
4. Costs at the End of the Quarter = $58,366
5. Carryover into the Next FY = $0

## ACCOMPLISHMENTS

- We completed delivery of the experimental portion of a Hands-On criticality safety course for NCSEs in February 2018.
- At the end of the quarter we were preparing for April delivery of a Hands-On criticality safety course for managers.

## MILESTONES

Conduct hands-on training classes at Sandia and provide Human Factors and Equipment Reliability module support to the training courses in accordance with the approved schedule (TE1: All Qtrs). 

## ISSUES/PATH FORWARD

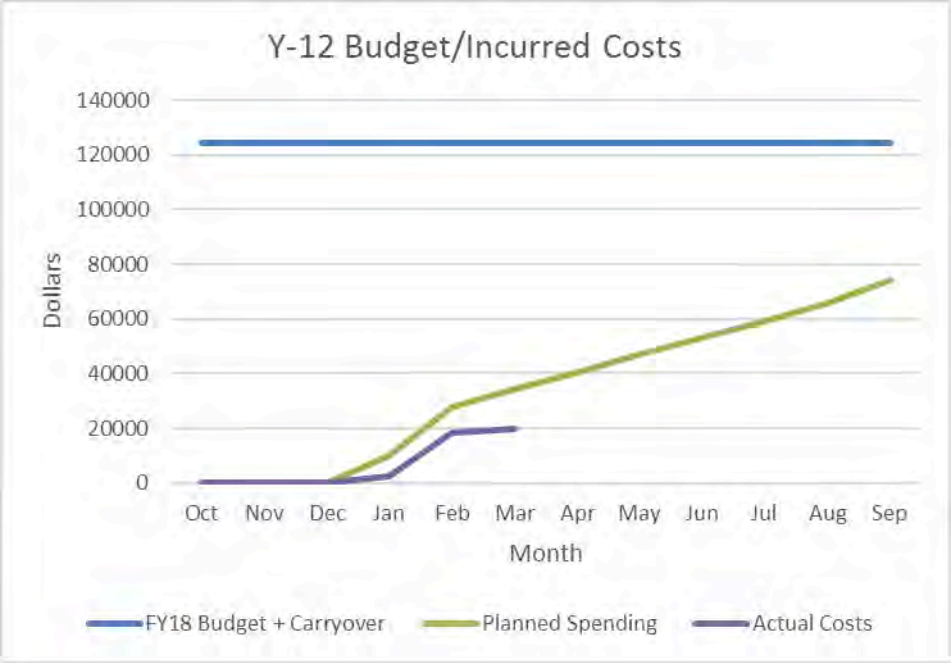
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

NCSP Element and Subtask: Y12-T&E1 (Conduct Hands-On Criticality Safety Training Course)
M&O Contractor Name: Y-12
Point of Contact Name: Kevin Kimball
Point of Contact Phone: 865-576-6675

Reference: B&R DP 0902017
Date of Report: April 6, 2018


## BUDGET




1. Approved FY-2018 Budget = $124,273; CR To Date = $124,273
2. Actual Spending through the end of this quarter in FY-2018 = $19,606

## ACCOMPLISHMENTS

- Taught Hand Calculations and the CSE Workshop in the course held in Las Vegas January 29th through February 2nd
- Began revising Hand Calculation material per feedback received in last course (25% complete)

## MILESTONES

| | |
|---|---|
| Support NCSP Hands On Training (Q1) | |
| Support NCSP Hands On Training (Q2) | |
| Support NCSP Hands On Training (Q3) | |
| Support NCSP Hands On Training (Q4) | |

## ISSUES/PATH FORWARD

- Complete changes to Hand Calculation material
- Develop new LEU CSE for workshop
- Teach revised Hand Calculations and CSE Workshop in the course scheduled for August 13th through 17th

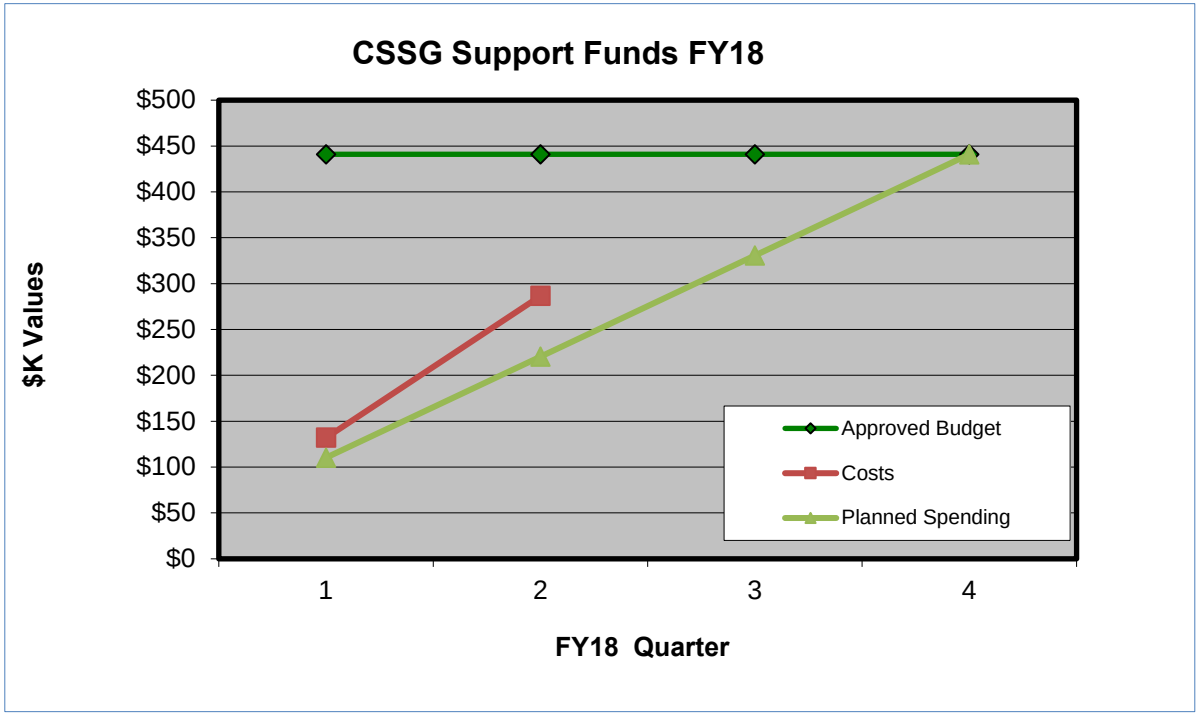
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY18 Q1)

NCSP Element and Subtask: CSSG Support
M&O Contractor Name(s): AECOM, ANL, LANL, LLNL, PNNL, SRNS, Y-12
Point of Contact Name: David Hayes (CSSG Deputy Chair)
Point of Contact Phone: 505-667-4523

Reference: B&R DP 0902010
Date of Report: May11, 2018


## BUDGET




a) Total Budget for FY18 = $441K
b) Actual Total Spending for FY18 = $287K
Q1 = $132K, Q2 = $155K, Q3 = $0K, Q4 = $0K

## ACCOMPLISHMENTS

- CSSG Chair/Deputy duties
- CSSG conference calls
- Prepare/Review taskings/responses (2016-04, 2017-04, 2017-05)
- Support Technical Program Review
- High burn rate due to 2 week SRNS Review (2017-05) ~$128K

## MILESTONES

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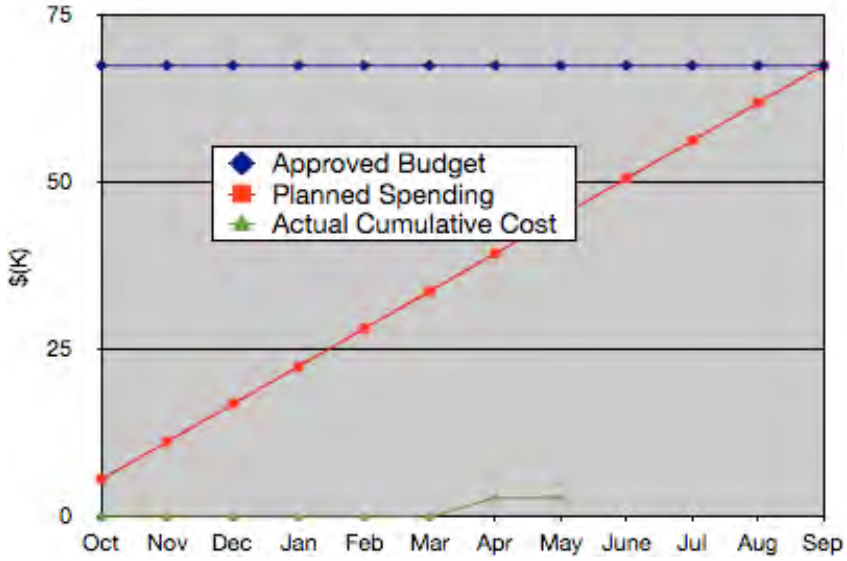
| Tasking 2016-04 Position of the CSSG on Natural Phenomena and Other Extreme Events vis-a-vis ANSI/ANS-8 Standards | |
| Tasking 2017-04 CSSG Review of LANL CSP | |
| Tasking 2017-05 CSSG Assessment of SRNS NCS Program | |
| | |
| | |

## ISSUES/PATH FORWARD

Face-to-Face Meeting in Philadelphia will be next big expenditure: Likely need increased budget for DKH, TPM, EFT

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

| NCSP Element and Subtask: NCSP Technical Support Task 6<br>M&O Contractor Name: BNL<br>Point of Contact Name: David Brown<br>Point of Contact Phone: 631-344-2814 | Reference: B&R DP 0902090<br>Date of Report: May 10, 2018<br>Page 1 of 1 |
|---|---|
| **BUDGET** | **ACCOMPLISHMENTS** |
|  <br>1. Carryover into FY-2018 = $0<br>2. Approved FY-2018 Budget = $2,897 (Includes carryover from FY-2017)<br>3. Actual Spending through the end of this quarter in FY-2018 = $0 | · Work on this task has just begun |
| **MILESTONES** | **ISSUES/PATH FORWARD** |
| Provide NCSP Manager annual report of succession planning efforts (Q4) | |

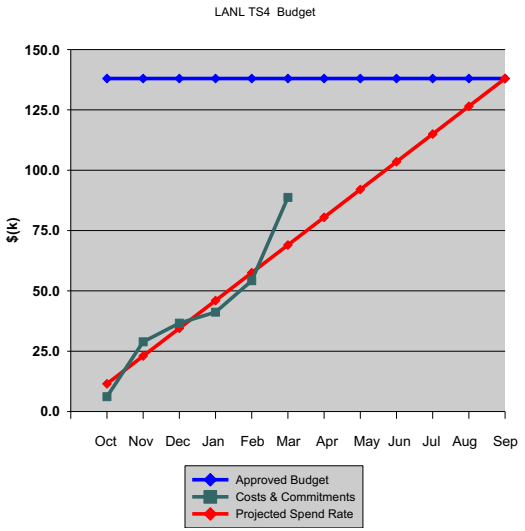
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

**NCSP Element:** Integral Experiments LANL TS 4
**M&O Contractor Name:** Los Alamos National Laboratory (LANL)
**Point of Contact Name:** Robert Margevicius
**Point of Contact Phone:** (505) 665-8965

Reference: B&R DP0902090
Date of Report: May 11, 2018

## BUDGET




1. **Carryover from last FY-17: $0.**
2. **Total available funding this FY-18: $138.0K**
3. **Total spending through the end of the report quarter Q2: $88.7K**
4. **Carryover into new FY-19: $0.**

## MAJOR ACCOMPLISHMENTS

- George McKenzie successfully defended his PhD dissertation entitled "Area of Application for Relating Reactivity to Rossi-Alpha". He completed all the requirements to earn his PhD in Nuclear Engineering from the University of Illinois.

## ISSUES/PATH FORWARD

- None

- None

# NCSP Quarterly Progress Report (FY-2018 Q2) cont'd.

| **NCSP Element:** Integral Experiments LANL TS 4<br>**M&O Contractor Name:** Los Alamos National Laboratory (LANL)<br>**Point of Contact Name:** Robert Margevicius<br>**Point of Contact Phone:** (505) 665-8965 | | Reference: B&R DP0902090<br>Date of Report: May 11, 2018<br>x | |
|---|---|---|---|
| **MILESTONES** | | **MILESTONES** | |
| • Provide status reports on succession planning activities in the NCSP Quarterly Progress Reports (TE1-T1). (Q1, Q2, Q3, Q4). | M | | |
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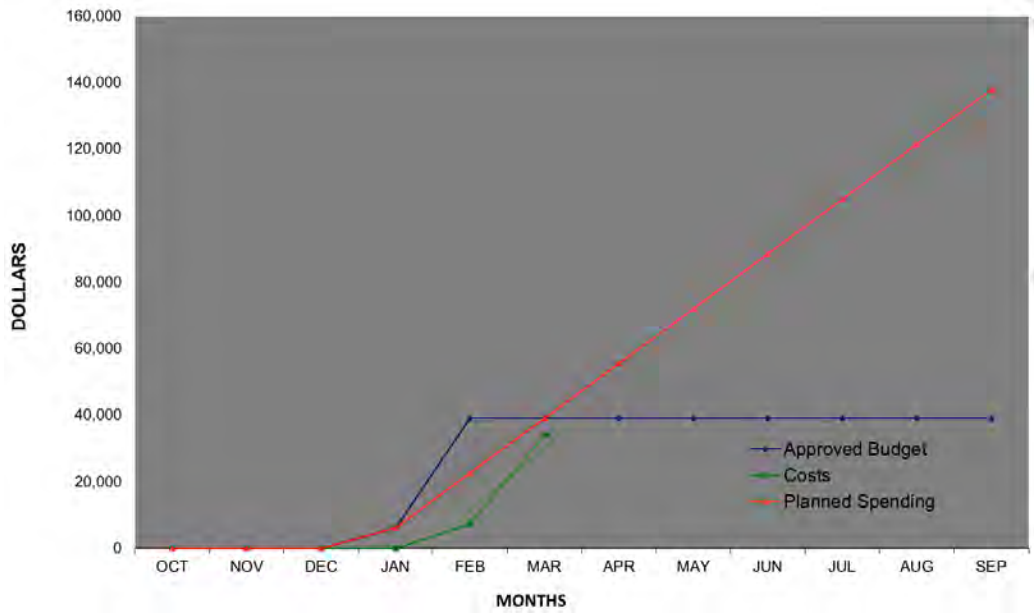
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed before or on Schedule, Purple = Completed Late

# NCSP Quarterly Progress Report (FY 2018 Q2)

NCSP Element and Subtasks: Technical Support
LLNL Succession Planning (TS5)
M&O Contractor Name: Lawrence Livermore National Laboratory
Point of Contact Name: David Heinrichs
Point of Contact Phone: (925) 424-5679

Reference: B&R DP0909010
Date of Report: May 11, 2018


## BUDGET




1. Carryover into FY-2018 = $0
2. Approved FY-2018 Budget = $138,000 (Includes carryover from FY-2017)
3. Actual Spending through the end of this quarter (in FY-2018) = $41,588
4. Projected carryover into FY-2019 = $0 (0%)

## ACCOMPLISHMENTS

Analytical Methods

- Jerome Verbeke integrated user-defined source and detector routines into the latest COG11.3 software baseline in support of IER-407 (executing part of the succession plan for Rich Buck, who separated from LLNL effective November 1, 2017).

Integral Experiments

- Tony Nelson presented "ISSA Preliminary Results" at the NCSP Technical Program Review at ORNL.
- Jesse Norris presented "Optimizing TEX-Pu for Testing Thermal Scattering Cross Sections and Maximizing the Intermediate Fission Fraction" at the NCSP Technical Program Review at ORNL winning an "NCSP Best Paper" Award.
- Doug McAvoy transitioning Responsible Individual responsibilities to Paul Yap-Chiongco in support of IE (NAD Lab).

Training and Education

- Shauntay Coleman attended the "hands-on" portion of the two-week CSE course at NCERC on February 5-9, 2018 as part of her qualification as "LLNL NMO TACS Instructor" in support of future NCSP T&E courses.
- Doug McAvoy transitioning NMO Project Lead responsibilities to Paul Yap-Chiongco in support of T&E (TACS).

## MILESTONES FY2018

| | |
|---|---|
| Provide NCSP Manager annual report of succession planning efforts (TS5). | |

## ISSUES/PATH FORWARD

- LLNL TS5 expenditures delayed one quarter due to Continuing Resolution; however, LLNL TS1 (CSSG) is instead fully funded.
- Approved budget reflects actual funds received on October 13, 2017; December 22, 2017; January 12, 2018; February 8, 2018; and February 27, 2018 (in excess of $50,000 reserved for LLNL TS1 (CSSG)).

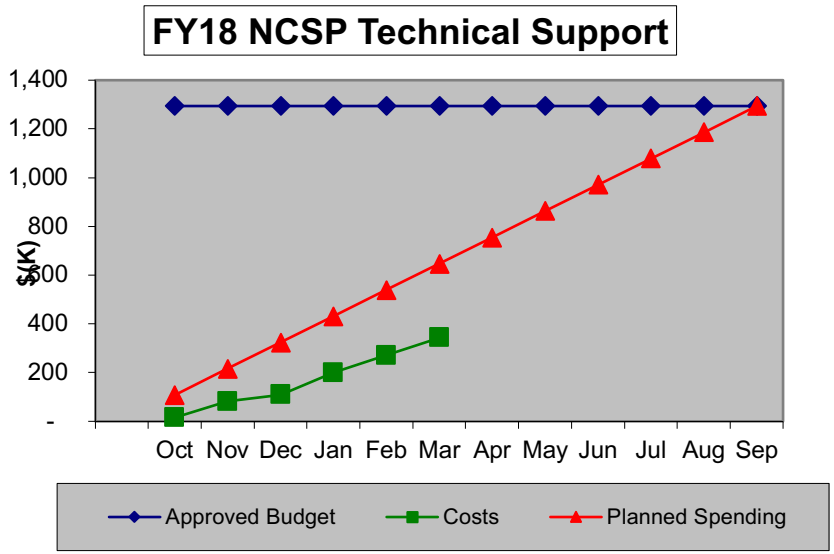
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

**NCSP Element and Subtask:** TS2 (NCSP Technical Support), TS7 (Succession Planning), TS8 (NCSP MGT Tool Prototype), TS11 (CEdT Manage Support)
**M&O Contractor Name:** ORNL
**Point of Contact Name:** Doug Bowen
**Point of Contact Phone:** (865) 576-0315

**Reference:** DP0902000/ORNL
**Date of Report:** May 1, 2018

## BUDGET




1. **Carryover into FY 2018** = $5K
2. **Approved FY 2017 Budget** = $1,294K (includes carryover)
3. **Actual spending for 1st quarter FY 2017** = $110K
4. **Actual spending for 2nd quarter FY 2017** = $0
5. **Actual spending for 3rd quarter FY 2017** = $0
6. **Projected carryover into FY 2018** = $0

## ACCOMPLISHMENTS

**NCSP TS2 Program MGT and Execution of the NCSP**

- Prepare and maintain elements of NCSP Plan and associated activities:
  - Monitor Five-Year Plan progress,
  - Review/revise task list, and
  - Schedule/participate in meetings and teleconferences.
  - Manage and provide oversight/coordinate efforts for the NCSP Information, Preservation, and Dissemination task element.
  - Manage and provide oversight/coordinate efforts for the NCSP Training and Education Program task element.
- Participated in weekly NCSP management team and other NCSP-related meetings, as required by the NCSP Manager.
- Bowen continued efforts to work with Tim Wynn (ORNL) and Ty Deschamp (NA-50) about tracking IERs in the G2 system. No timeframe for completion has been identified.
- Prepared Q1 QPRs into a single bookmarked PDF file for use in QPR. Conducted Q1 telecon.
- Began working on the spring NCSP newsletter – will release after the KRUSTY experiment is completed.
- Continued efforts to turn over CedT tasks from Doug Bowen to Thomas Miller.
- All BCRs for FY18 have been processed by CEdT Manager and a final IER status report was sent to the NCSP manager in March.
- Planned and hosted the Technical Program Review meeting at ORNL. Meeting had 90 participants.
- Hosted a CSSG meeting during the TPR week at ORNL to discuss CSSG business and to review/vet FY19 proposals.
- Initiated main and IE 5-year plans for FY19. Started work on generating the pre-decisional budget spreadsheet. Sent out University and General call for proposals to all sites. Organized proposals for the NCSP manager and the CSSG. CSSG completed a pre-screen of all university and general proposals. NOTE: some CSSG members are unaware that there is a call for both university and general proposals. Scott/Bowen identified this as an area of improvement with respect to program communication.
- Participated in CSSG telecons and assisted with CSSG tasks as necessary.
- Began efforts to improve documentation of NCSP accomplishments to ensure NCSP work is linked to final 5YP milestones.
- Hosted TPR and Mission and Vision meetings during the week of the TPR at ORNL.

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

| | |
|---|---|
| **NCSP Element and Subtask:** **TS2 (NCSP Technical Support), TS7 (Succession Planning), TS8 (NCSP MGT Tool Prototype), TS11 (CEdT Manage Support)**<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference:** DP0902000/ORNL<br>**Date of Report:** May 1, 2018 |
| | **NCSP TS7 Succession Planning**<br>• New ORNL Post Doc (Christopher Chapman) and new ORNL staff member (Andrew Holcomb) working on Nuclear Data (SAMMY/AMPX) tasks with the nuclear data team leader and staff. In Q1, Chris Chapman began to work on nuclear data evaluations with Vlad Sobes as a mentor.<br>• ORNL junior R&D staff (Vlad Sobes) working with Luiz Leal on NCSP ND evaluation work.<br>**NCSP TS8 NCSP MGT Tool**<br>• Continued work on an initial prototype of a new NCSP Program Management Tool began in FY17Q3. Prototype system planning for incorporating the IER process in the NNSA G2 accounting system initiated in FY18Q1 for the IER process. Further work is pending for the NCSP 5YP project management tools, although new needs have been identified. Metrics capability will not be part of the prototype. Scope of the project is in development. |

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP QUARTERLY PROGRESS REPORT (FY 2018 Q2)

| | |
|---|---|
| **NCSP Element and Subtask:** TS2 (NCSP Technical Support), TS7 (Succession Planning), TS8 (NCSP MGT Tool Prototype), TS11 (CEdT Manage Support)<br>**M&O Contractor Name:** ORNL<br>**Point of Contact Name:** Doug Bowen<br>**Point of Contact Phone:** (865) 576-0315 | **Reference:** DP0902000/ORNL<br>**Date of Report:** May 1, 2018<br>**Page 3 of 3** |

| MILESTONES | Status | ISSUES/RESOLUTIONS |
|---|---|---|
| 1. Manage $C_E$dT process and coordinate execution of planned IERs each FY. (TS2 All QTRs) | | |
| 2. Maintain up-to-date spreadsheet of proposed tasks for NCSP Manager after the NCSP proposal review meeting and through the final task prioritization effort by the NCSP Management Team. (TS2 All QTRs) | | |
| 3. Provide the NCSP manager with a summary of NCSP IE task TS11 as described in the task description. (TS11 All QTRs) | | |
| 4. Participate in Q4 Budget Execution Meeting and assist NCSP Manager in finalization of approved tasks for next FY. (TS2 Q4) | | |
| 5. Publish final Five-Year Plan. (TS2 Q4) | | |
| 6. Provide NCSP Manager annual report of succession planning efforts. (TS7 Q4) | | |
| 7. Provide NCSP Manager a status report of progress on the development of a program management tool. (TS8 Q4) | | |

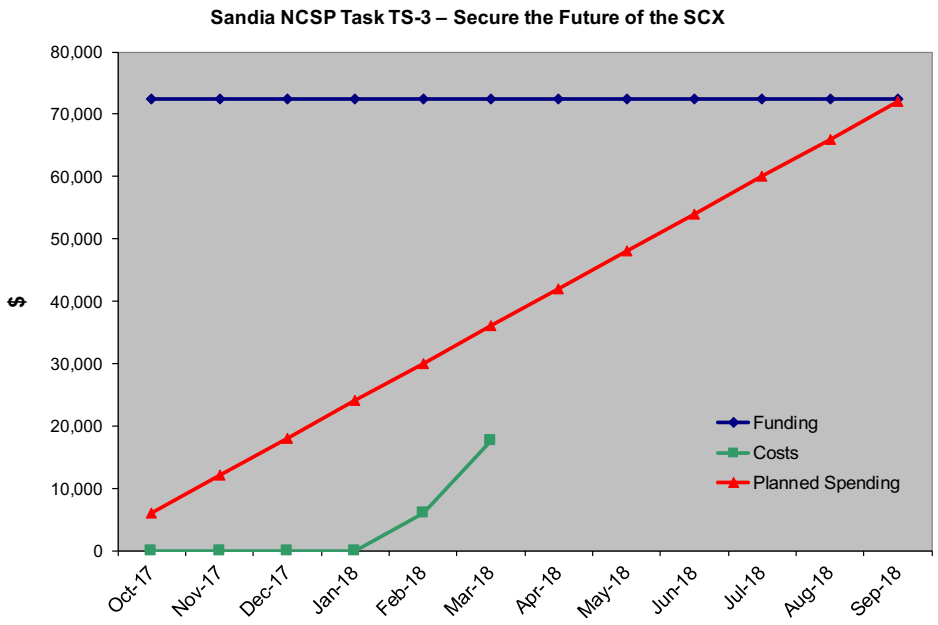
Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

# NCSP Quarterly Progress Report (FY-2018 Q2)

NCSP Element: Sandia TS3 – Secure the Future of the SCX
M&O Contractor Name: Sandia National Laboratories (SNL)
Point of Contact Name: Gary A. Harms
Point of Contact Phone: (505)845-3244

Reference: B&R DP 0909010
Date of Report: March 31, 2018


## BUDGET




1. Carryover from the Previous FY = $1,695
2. Total Funding Available This FY: $70,670 (new) + $1,695 (carryover) = $72,365
3. Approved Current FY Budget = $72,000
4. Costs at the End of the Quarter = $17,500
5. Carryover into the Next FY = $0

## ACCOMPLISHMENTS

- We have a matrixed employee who is being trained as an experimenter.
- The new experimenter is documenting the IER-451 experiments.

## MILESTONES

| | |
|---|---|
| Develop critical experimentalists | |

## ISSUES/PATH FORWARD

None.

Green = On Schedule, Yellow = Behind Schedule, Red = Missed Milestone, Blue = Completed

2018-04-01

**Summary of Recent Classes**

F.B. Brown, M.E. Rising, J.L. Alwin
Monte Carlo Methods, Codes, & Applications Group (XCP-3), LANL

FY2018 – Q2 classes are highlighted in red.

## Classes sponsored by DOE-NNSA-NCSP (LANL-AM1)

- **Sensitivity-Uncertainty Tools & Practices for NCS Validation**
  - Aug 7, 2017, ORNL, 15 participants
  - Aug 8, 2017, Y-12, 15 students
  - Apr 23, 2018, Savannah River, 14 students

  This is a joint effort between LANL & ORNL, covering background material and specific usage of MCNP6-Whisper and SCALE-KENO-TSUNAMI-TSURFER. D. Bowen coordinates scheduling at DOE sites.

- **Criticality Calculations with MCNP6**
  - Aug 14-18, 2017, LANL, 12 students
  - Feb 26 – Mar 2, 2018, LANL, 4 students
  - June 11-14, 2018, Y-12,
  - Aug 6-10, 2018, LANL,

  MCNP criticality class for NCS & reactor physics practitioners, with focus on best practices. Includes 1 day on NCS validation using MCNP6-Whisper.

  For classes at LANL, NCSP-sponsored students do not pay registration fees. For classes at other DOE sites, there are no registration fees.

- **Monte Carlo Techniques for Nuclear Systems**
  - Aug 25 – Dec 8, 2017, UNM, 18 students

  This is a 1-semester class for senior undergrads & graduate students at the University of New Mexico. Required for UNM graduation in Nuclear Engineering. Includes Monte Carlo theory & practical use of MCNP6. 2 of the students were part of the LANL NCS intern program. (This teaching is partially supported by NCSP, ASC, and other programs.)

- **Advanced Computational Methods for Monte Carlo Calculations**
  - Jan 17–May 9, 2018, UNM & LANL, 8 students UNM, ~12 LANL

  This is an advanced class covering details of transport theory, Monte Carlo, advanced computing methods, and code development. Material from this course is also used to teach LANL staff members. (This teaching is partially supported by NCSP, ASC, and other programs.

## Other Classes (LANL-AM1)

- **Introduction to MCNP6**
  - Dec 4-8, 2017, LANL, 15 students
  - Dec 11-15, 2017, NCSU, 30 students
  - Jan 8-12, 2018, LANL, 15 students
  - Apr 2-6, 2018, LANL,
  - June 4-8, 2018, LANL,
  - Aug 13-17, 2018, LANL,
  - Dec 3-7, 2018, LANL,

  Standard introductory class, includes 1/2 day on criticality calculations. Classes at LANL are supported by student registration fees.

  The class at North Carolina State University (NCSU) included undergraduate & graduate students. This was the first off-site class in 10 years that was not held at a DOE site.

| Class Name | Class Dates | Location | No. of Students | Description |
|---|---|---|---|---|
| SCALE/ORIGEN Fuel Depletion, Activation and Source Term Analysis Course | Feb 12 - Feb 16, 2018 | Oak Ridge National Laboratory, Oak Ridge, TN | 11 | This is a hands-on class that covers the use of ORIGEN for isotopic depletion, decay, decay heat, and radiation source-terms calculations. The course features the use of the Fulcrum consolidated SCALE graphical interface and Fulcrum plotting capabilities for displaying nuclear data and results. The class includes solving activation, spent fuel, and nuclear safeguards and security analyses. This class provides an introduction to the ORIGAMI tool for convenient characterization of spent nuclear fuel with radially and axially varying burnup. |
| SCALE Criticality Safety Calculations (KENO-V.a and KENO-VI) Course | Feb 19 - Feb 23, 2018 | Oak Ridge National Laboratory, Oak Ridge, TN | 11 | This course provides instruction on the use of the KENO Monte Carlo codes for criticality safety calculations and is appropriate for beginning through advanced users. KENO V.a is a fast and easy-to-use code that allows users to build complex geometry models using basic geometrical bodies such as cuboids, spheres, cylinders, hemispheres, and hemicylinders. KENO-VI is a 3-D generalized geometry Monte Carlo code that allows for versatile modeling of complex geometries. Both versions of KENO provide convenient, efficient methods for modeling repeated and nested geometry configurations such as lattices. Both versions of KENO use ENDF/B-VII.0 or ENDF/B-VII.1 cross-section data distributed with SCALE to perform either continuous energy (CE) or multigroup (MG) calculations. KENO includes a 2D color plotting capability and produces easy-to-navigate HTML output. This class uses the Fulcrum |

| Class Name | Class Dates | Location | No. of Students | Description |
|---|---|---|---|---|
| SCALE/Polaris Lattice Physics, Depletion, and Uncertainty Analysis | Mar 5 - Mar 9, 2018 | NEA Databank, Paris, France | 11 | Polaris is a new 2-dimensional (2-D) lattice physics capability in the SCALE code system for LWR analysis. Polaris provides an easy-to-use input for defining lattice geometries, material compositions, and reactor state conditions. Other features of Polaris include a new resonance self-shielding implementation based on the novel embedded self-shielding method (ESSM), a new 2-D method of characteristics (MOC) neutron transport solver, and the integration of the ORIGEN depletion and decay solver for depleting material compositions. For the first three days of this five days course, attendees will learn how to model typical PWR and BWR assemblies (VVER currently not supported): develop geometry models, perform depletion simulations, setup branch and history calculations to generate few-group cross sections for full-core nodal diffusion analysis (.t16 file), and perform reflector calculations.<br><br>Sampler is a new uncertainty analysis capability in SCALE that propagates uncertainties in nuclear data and input parameters to estimate the resulting uncertainty in calculated responses for most codes and sequences within the SCALE code system. Using stochastic sampling to generate perturbed calculation models, Sampler can automate multiple runs (i.e. samples) of a calculation model and then post-process the outputs to quantify the uncertainty in user-selected quantities of interest. In the final two days of this course, attendees will learn how to use Sampler with Polaris to quantity |

| Class Name | Class Dates | Location | No. of Students | Description |
|---|---|---|---|---|
| Source Terms and Radiation Shielding for Spent Fuel Transportation and Storage Applications | Mar 12 - 16, 2018 | NEA Databank, Paris, France | 15 | One of the unique features of the SCALE code system is the flexibility of assembling different SCALE codes or sequences to solve complex problems. Transportation and storage of spent fuel require a computational tool set to characterize both the spent fuel source terms and the doses for containers used to transport or store the fuel. Spent fuel is a complex neutron and photon source that can be well characterized using the ORIGEN code in SCALE. Additionally, ORIGEN can be used to characterize the radioactive sources resulting from activation of non-fissile materials and components in a nuclear reactor, such as the pressure vessel. The variety of source terms generated with ORIGEN can be used for shielding analyses with the MAVRIC sequence. MAVRIC can estimate particle fluxes and dose rates outside of containers, to ensure that the safety requirements for transportation, storage and ultimate disposal of spent fuel or activated materials are met.<br><br>This one-week course will first cover the use of ORIGEN for isotopic depletion, decay and radiation source-terms calculation, generation of ORIGEN activation libraries, and the use of the ORIGAMI tool for quick calculation of spent fuel sources. The next part of the course will focus on |

| Class Name | Class Dates | Location | No. of Students | Description |
|---|---|---|---|---|
| Criticality Safety and Radiation Shielding | Mar 5 - Mar 9, 2018 | North Carolina State University | 12 | This course provides instruction on the use of the KENO-VI Monte Carlo code for criticality safety calculations and the MAVRIC (Monaco with Automated Variance Reduction using Importance Calculations) shielding sequence with 3-D automated variance reduction for deep-penetration problems. KENO-VI is a 3D eigenvalue Monte Carlo code for criticality safety and Monaco is a 3D fixed-source Monte Carlo code for shielding analysis. Both codes use the SCALE Standard Composition Library and the SCALE Generalized Geometry Package (SGGP), which allows for versatile modeling of complex geometries and provides convenient, efficient methods for modeling repeated and nested geometry configurations such as lattices. The MAVRIC sequence is based on the CADIS (Consistent Adjoint Driven Importance Sampling) methodology. For a given tally in a Monte Carlo calculation that the users wants to optimize, the CADIS method uses the result of an adjoint calculation from the Denovo 3D deterministic code to create both an importance map for weight windows and a biased source distribution. MAVRIC is completely automated in that from a single user input, it creates the cross sections (forward and adjoint), computes the adjoint fluxes, creates the importance map and biased source, and then executes Monaco. An extension to the |